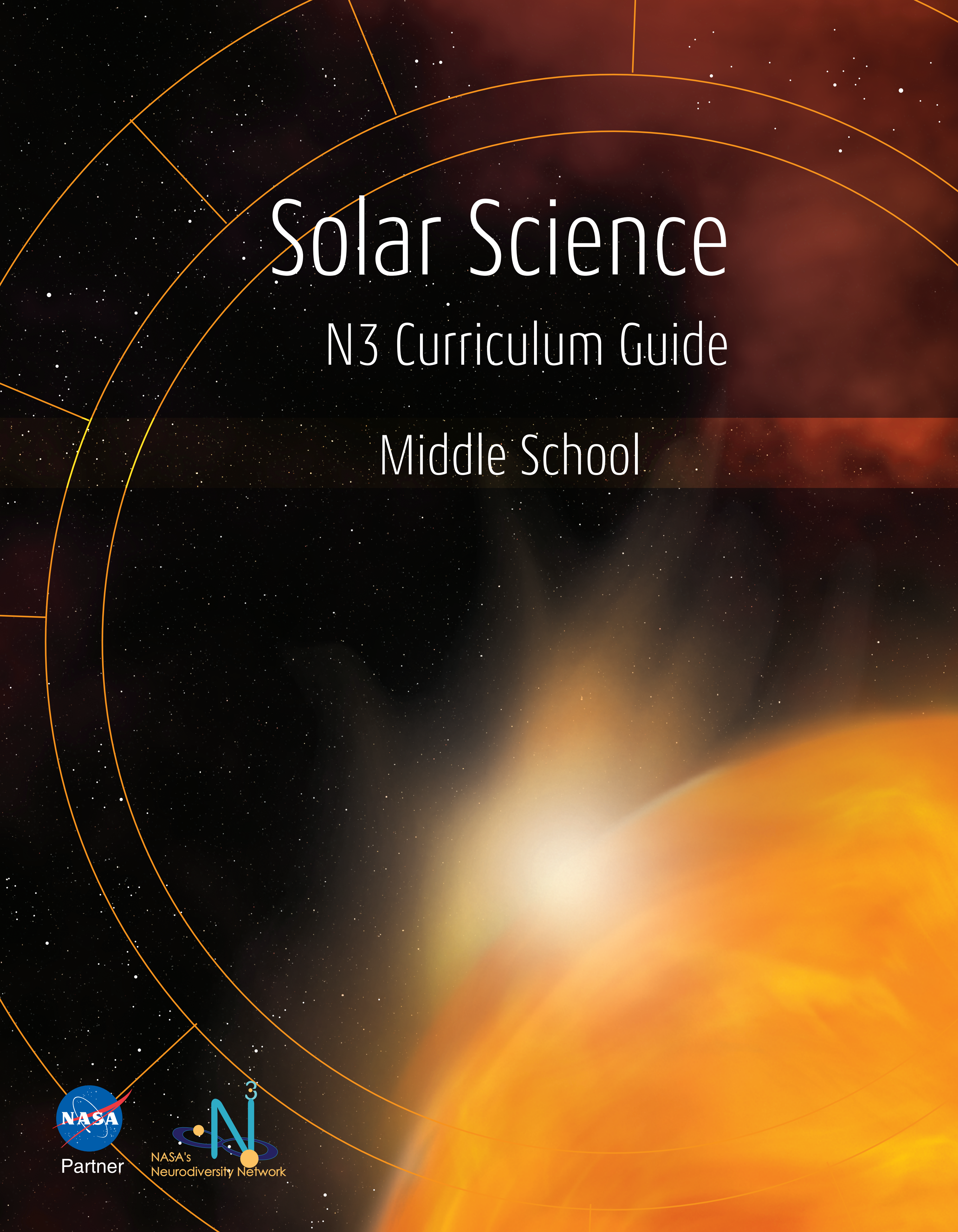


Solar Science

N3 Curriculum Guide

Middle School

Content

Introduction

Welcome to the Solar Science Middle School Camp Curriculum!

This project is made possible through NASA's Neurodiversity Network (N3), a Science Activation program led by Sonoma State University in partnership with the New York Hall of Science, Education Development Center, WestEd. N3 is funded through NASA Cooperative Agreement #80NSSC21M0004. This curriculum is intended to support a camp designed for middle school neurodivergent students. For more information on N3 curricula that have been co-designed with neurodivergent learners, see ***https://n3.sonoma.edu/curriculum/home***

This Solar Science curriculum is centered on real life events, and it has been designed to encourage students to follow their own curiosity and interests in investigating these events. It was originally designed for high school students, and then adapted for middle schoolers. Several middle school students were invited to assist with the creation of this curriculum, through the co-design process. The lessons in this guide have greatly benefited from the feedback given to us by our neurodivergent student partners after doing the activities themselves.

The Sun impacts daily life on our planet in a myriad of ways, from the light and warmth we need to survive, to lesser known effects such as solar storms that are able to disrupt communications on Earth. This exciting Solar System curriculum invites students to consider how the Sun impacts their own lives as they explore the mysterious events that drive these lessons.

Programmatic Structure

This camp is structured around a series of Solar Mysteries, which are introduced in the first activity. These mysteries provide the impetus for the rest of the investigation, and are a pillar of the intended daily structure of camp. The entire program is designed around solving these mysteries. It is essential for instructors to start the camp with the Solar Mysteries activity and to conclude it by revisiting the Solar Mysteries, ensuring that each mystery is resolved to the campers' satisfaction. It is also highly recommended to return to the mysteries each day to allow campers to share what they have learned, and ask any additional questions they still have about the mysterious events.

The activities in this curriculum are centered around general knowledge about the Sun, or explore specific aspects of the mysterious events. It is recommended to start your program's exploration of the events with general Sun knowledge, then move towards the activities that deal with the mysterious events specifically.

This camp was designed to take place over two weeks, or ten total days of camp. This schedule allows instructors plenty of time to fit in other standard camp activities such as games, crafts, and team building activities that support crucial socio-emotional learning during the program. Two weeks also gives instructors more customization in scheduling activities, and allows some flex time so instructors can adapt to their camper's needs. Flexibility is always recommended as best practice with working with neurodivergent students, and all lessons and activities can and should be adjusted to best fit the specific needs and interests of the individual campers in the program.

Each lesson is broken down into easily digestible parts. We start with quick organizational information such as: lesson objectives, duration, materials needed, key vocabulary covered, and any preparation that needs to happen prior to the activity. This is also where ueful tips are located. Every lesson is designed to be suited for many types of learners, however some activities may have additional tips or considerations to make when determining how to best support your individual campers.

The procedure lists the detailed step-by-step instructions for leading the activity. For some activities, pictures may be included in this section as well. After the procedure, there may be extension ideas to further explore this concept. Finally, each lesson includes an explainer on the science concepts specifically within the lesson and any background information that might be helpful for teaching the activity comprehensively. At the end of the lesson, any additional resources used within the lesson are listed.

Additional resources including a complete materials list, example companion slides, and an example camp schedule are included to support camp implementation. These additional resources include all fourteen activities from the curriculum guide, many of which connect back to the Solar Mysteries. If you choose to remove lessons, please also remove the associated mystery card. It is important that the campers are not left with loose ends or mysteries they can't solve. If you remove "Aurora Art" or "Magnetic Fields" from the curriculum, please remove both "Strange Red Sky" mystery cards as well. If you remove "Power Outages" from the curriculum, please remove the "Power Outages in Northern Cities," "1859 Carrington Event," "Electrical Blackout in Sweden," "Power Outages in Midwestern States," and "Southeastern States Experience Power Loss" mystery cards.

Session 1: Solar Mysteries

Activity Overview:

Students will be presented with a series of mysterious events that seem unconnected, but all relate to increased solar activity. This is an ongoing activity that students will try to solve throughout the camp as they learn about solar behavior.

Duration:

- **First Day:** 30 min
- **Subsequent Days:** 15 min
- **Final Day:** 30 min

Preparation:

Print and laminate mystery card sets. You'll need these throughout the week, so keep them in an accessible part of the classroom.

Materials:

- Printed *mystery cards* (preferably laminated)
- Chart paper
- Markers
- Scrap paper or notebooks
- Pencils

Key Terms:

Corona: The Sun's outermost layer.

Coronal Mass Ejections (CMEs): Huge bubbles of the Sun's plasma that are ejected from the Sun into outer space.

Solar Flares: An intense burst of radiation released by magnetic energy from sunspots and seen as a bright flash of light.

Activity Procedure: First Day:

1. Inform the students that there have been strange occurrences observed by NASA, and that the students are needed to look over the events and see if they notice any connections.
2. Suggest they work in groups of 2-3.
3. Distribute the cards and give students ~10 minutes to study the images and read the stories .
4. Hand out notebooks/scrap paper and pencils. Encourage students to write or sketch their ideas and thoughts about the cards. This can include theories, things they wonder, and things they already know.
5. Guide students towards noticing the connections between the events. They should look at the dates, locations, types of events, etc.
6. Once they have had enough time to come up with ideas, lead a group share-out where each group discusses their thoughts, observations, and theories. Record their thoughts on chart paper so you can refer back to them throughout the program.

Useful Tip:
While working collaboratively is encouraged for this activity, group work can be stressful for some learners. Therefore, it is recommended to have extra sets of cards available for those who wish to work individually.

Activity Procedure: Subsequent Days

1. At the end of each day, review the solar mysteries and update the chart paper with what they have learned.
2. Continue recording the theories and questions that students may have about the mysterious events.

Activity Procedure: Final Day

1. Using the knowledge taught throughout the program, review the mystery events and make sure that students can make connections between increased solar activity and the recorded events.

Important Activity Information

The Solar Mysteries activity provides the central framework for the program, and is used as a jumping off point for all subsequent activities. This activity opens up questions that students will explore through the remainder of the camp. To help students make connections between the activities, facilitators must refer to the mysteries regularly, and encourage students to share their theories and thinking on the subject.

This program is learner-directed, and the students' curiosities and questions about the mysteries should help shape the direction of the other activities. While other activities can be scaled down or skipped if needed, it is recommended that this activity be followed as written to ensure that the remainder of the activities feel cohesive and purposeful.

If activities need to be skipped, facilitators then need to consider how to best scaffold the program so there isn't a hole in the content. The Solar Mysteries span several topics, such as power/electrical grid failures, satellite/GPS failures, increased auroral activity, and increased radiation. If an activity is skipped, it is suggested that facilitators remove the mystery card that corresponds to the activity's topic. Ex: if the electricity activity is skipped, then remove the mystery card relating to electricity. This will prevent confusion and frustration for the campers.

Background Science:

The Sun is an active star with very inconsistent behaviors. Our Sun has a 22-year cycle (called the **solar cycle**), during which there is increased solar activity for 11 years, followed by decreased solar activity for 11 years.

The Sun is made of active, electrically charged gas that creates a magnetic field. Every 11 years, the Sun's north and south poles swap, and the magnetic field flips. When areas of the Sun have particularly strong magnetic fields, they appear darker (because they are cooler) and are called **sunspots**. When the Sun is more active, there will be more sunspots and more solar activity.

Near the sunspots, the magnetic field lines move and get tangled, which can cause a sudden burst of radiation called a **solar flare**. When the field lines reorganize, they produce **coronal mass ejections (CMEs)**, which are ejections of radiation and particles from the Sun's outermost layer, the **corona**. When CMEs occur, the charged particles race across our solar system and often find their way to Earth. These can be thought of as solar storms, which aren't too dissimilar from thunderstorms in our atmosphere.

When CMEs reach Earth, we experience their impact in a variety of ways. One of the most beautiful impacts of CMEs is increased aurora activity. When the Sun's charged particles interact with Earth's magnetic field, a series of events can lead to a colorful reaction in the oval band surrounding the magnetic poles. The colorful reaction is known as the aurora. Different gases in our atmosphere react to the charged particles in different ways, creating dancing lights in different colors. While this typically happens in the far northern (or far southern) sky, it can happen in a much wider geographic range during periods of increased solar activity. In the late spring of 2024, people as far south as the Galapagos Islands were able to see faint traces of the aurora.

Background Science (continued):

Another way CMEs can affect Earth is by creating power surges that our electrical grid isn't always prepared to handle. During some solar storms, power outages occur as the grid struggles to deal with the surge. During the Great Carrington Event in 1859, a solar flare caused the telegram system to dramatically malfunction. Solar storms caused sparks to jump from telegraph pylons, and telegraph papers caught on fire! While this was almost two centuries ago, solar storms still affect our power grid, with more recent major blackouts occurring in 1989 and 2004. Some instructors and parents may have memories of these events.

While these solar storms bring increased radiation, our atmosphere does a good job of (mostly) shielding us. However, people traveling by airplane on certain flights and astronauts on the International Space Station may experience sudden bursts of energetic radiation and need to take shelter for safety.

Sources:

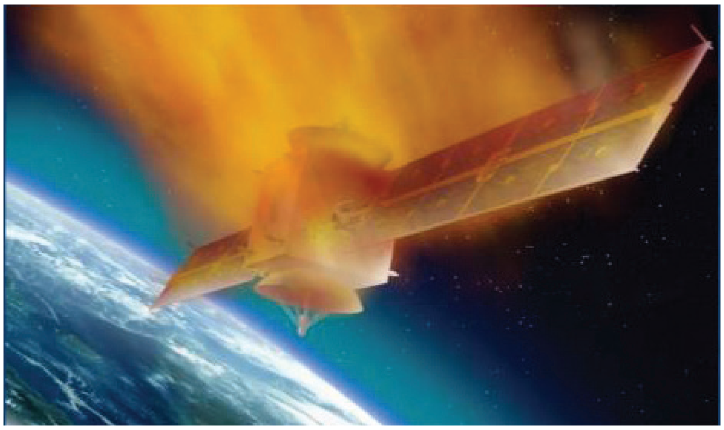
https://www.nasa.gov/image-article/what-solar-flare/#:~:text=A%20solar%20flare%20is%20an,last%20from%20minutes%20to%20hours.

https://www.jpl.nasa.gov/nmp/st5/SCIENCE/cme.html#:~:text=Coronal%20mass%20ejections%20(CMEs)%20are,scientists%20call%20%22flux%20rope.%22

https://blogs.nasa.gov/solarcycle25/2022/06/10/solar-flares-faqs/#:~:text=What%20is%20the%20difference%20between,of%20plasma%20and%20magnetic%20field.)

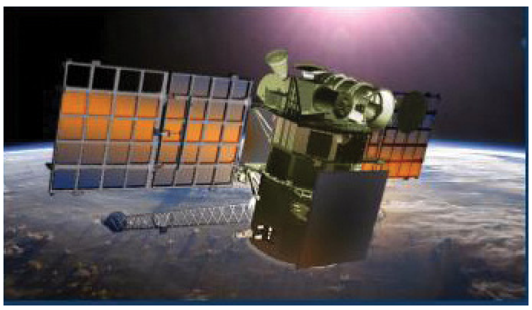
https://science.nasa.gov/sun/facts/

SpaceX Satellites



Over the past three years, SpaceX has deployed over 2000 satellites providing wireless high-speed internet from space using its Earth-orbiting Starlink network. On February 3, 2022, SpaceX launched 49 Starlink satellites. Within 5 days, 38 of those satellites lost altitude and burned up in Earth's atmosphere. The botched launch is estimated to cost between 50 and 100 million dollars.

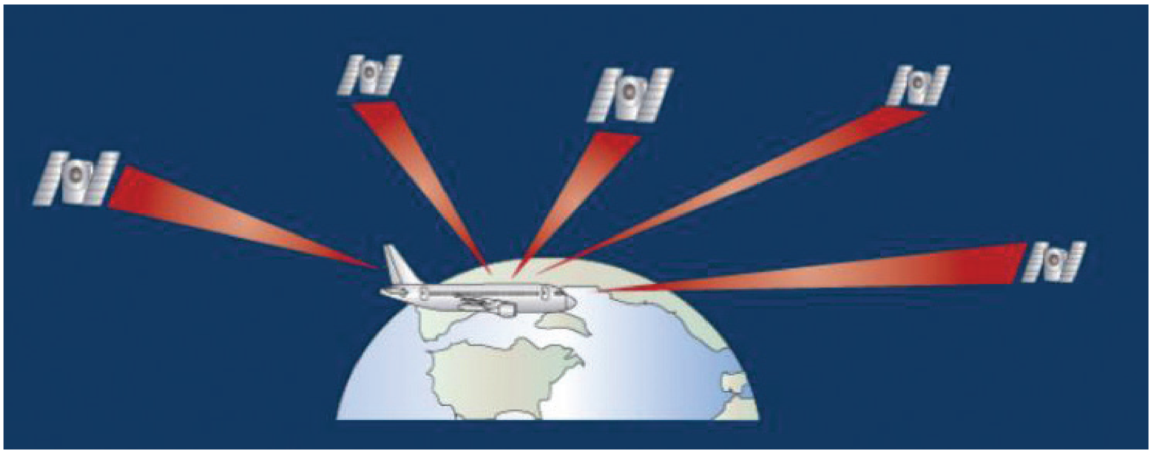
Halloween 2003 Satellite Malfunction



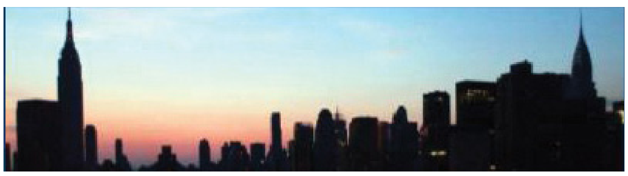
During a period of two weeks around Halloween of 2003, more than half of NASA's deep space and near-Earth space science missions experienced various failures. The Solar and Heliospheric Observatory (SOHO) satellite failed temporarily and NASA's Advanced Composition Explorer (ACE) satellite was damaged with all the scientific instruments needing to be shut down. Astronauts aboard the International Space Station (ISS) had to stay inside the more shielded parts of the Russian Orbital Segment to protect themsleves against increased radiation levels.

Mysterious GPS Failures

On December 6, 2006, a "widespread" loss of GPS in the four corners region of New Mexico and Colorado was reported by the military. Several aircraft reported losing GPS lock with the signal from as many as 12 satellites being dropped.



Power Outages in Northern Cities



On March 13, 1989, the electrical grid in the Canadian province of Quebec lost power. The outages not only affected Canada, they spread to other municipalities in the United States. New York Power lost 150 megawatts and the New England Power Pool lost 1,410 megawatts. Electrical service to 96 utilities in New England was disrupted. Over 200 power grid problems erupted across the U.S. within minutes of the blackout event. Power generation reserves were quickly brought online preventing the blackout from spreading to a wider area. In a single moment, 5 million poeple found themselves in dark office buildings, pedestrian tunnels, and elevators. Schools and most businesses remained closed throughout the duration of the power outage lasting more than 9 hours in length.

Electrical Blackout in Sweden

On October 30, 2003, part of high voltage power transmission system in southern Sweden was knocked off-line. The blackout lasted for an hour and left about 50,000 people without electrical power.

Strange Red Sky Over the Mojave Desert

During the pre-dawn hours of July 27, 2004, southern California experienced strange colors in the sky. These colors ranged from an intense ray of red sky to streaks of blues appearing above a pinkish orange horizon from the northeast.

Strange Red Sky Over Texas

On October 31, 2003, a bizarre red glow stretched throughout the sky as far south as Georgia, California, New Mexico, Arizona, Texas, and Oklahoma.

Radiation Doses on Flights

On April 15, 2001, a commercial flight from Frankfurt to Dallas - Fort Worth flying 39,000 feet above sea level carried a radiation dosimeter measuring a sudden onset, peak, and decay of radiation levels during the flight. The measurement showed a dose of ionizing radiation that increased by a factor of 2 to 2.5 above background levels lasting approximatley 3 hours.

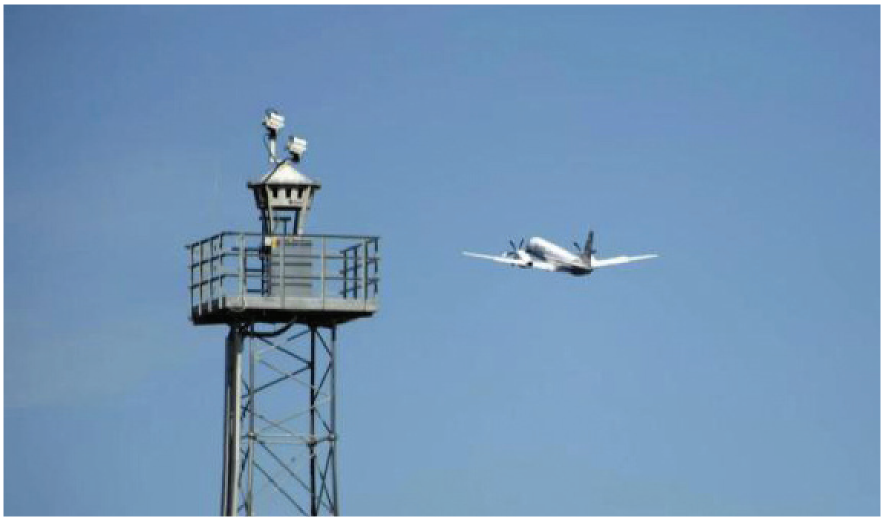
Power Outages in Midwestern States

On March 26, 2023, multiple midwestern and northern states experienced power outages. Over 600,000 people were inpacted by the blackout.

Southeastern States Experience Power Loss

From October 10 to October 20, 2018, 1.7 million people experienced power outages in the United State's southeastern states. The hardest hit states were Virginia and North Carolina, however six states were affected by the loss. In Virginia, 523,000 customers were left without power by the second day of this event.

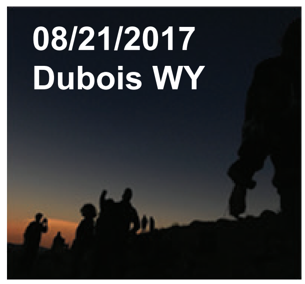
Air Traffic Control Blackout

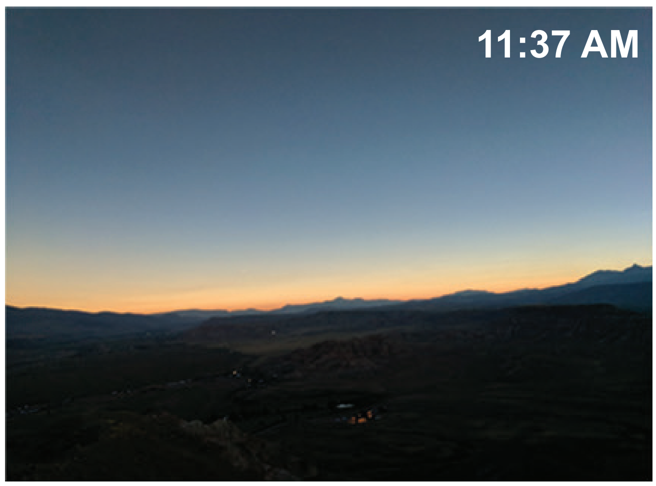


In November of 2015, Sweden's air traffic control experienced a complete system blackout. Every plane disappeared from the radar screens for more than an hour. Sweden's Civil Aviation Authorty closed the country's airspace from travel during the outage.

Light...Then Dark!

It got dark and cold in the middle of the day. The birds stopped chirping. The Sun disappeared and came back again a few minutes later. There were no clouds in the sky.





Session 2: Helioviewer

Activity Overview:

Students will use a digital tool called a Helioviewer to observe the Sun and gather real NASA data (both past and present).

Each day, the students will use the Helioviewer to observe and understand the Sun's current activity.

Additionally, students will use the Helioviewer to understand the Sun's past activity. Using the mystery cards, students will input the dates of these events into the Helioviewer and use the data to draw conclusions for the mystery events and develop their understanding of the Sun.

Duration:

- **First Day:** 30-40 min
- **Subsequent Days:** 20 min
- **Final Day:** 30 min

Preparation:

- On each laptop, open an internet browser and enter *student.helioviewer.org*
- Bookmark the website on the browser

Materials:

- Laptops (or any device with internet connection)
- Paper
- Pencils
- Colored pencils
- *Suggested Worksheet* or use your own journal or notebook for sketching

Key Terms:

Corona: The Sun's outermost layer.

Coronal Mass Ejections (CMEs): Huge bubbles of the Sun's plasma that are ejected from the Sun into outer space.

Solar Flares: An intense burst of radiation released by magnetic energy from sunspots and seen as a bright flash of light.

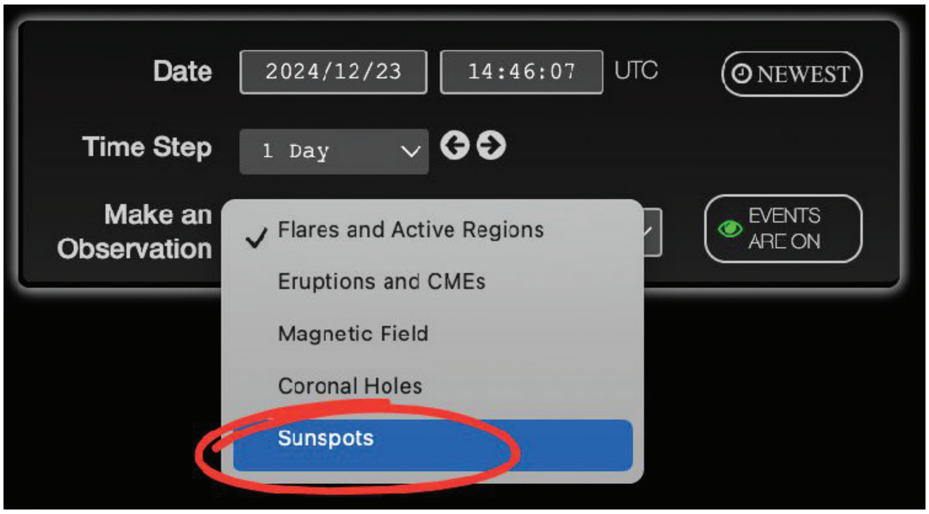
Sunspots: Areas of the Sun that appear darker because they have a stronger magnetic field and are cooler compared to other locations on the solar surface.

Active Regions: Areas on the Sun with large concentrations of magnetic fields. This is where solar activity (solar flares, CMEs) can occur.

Useful Tip:
Since this activity occurs each day, the timing can be flexible. Depending on student needs, it can be helpful to provide transition time after specific activities (such as lunch or outdoor play) before using the laptop.

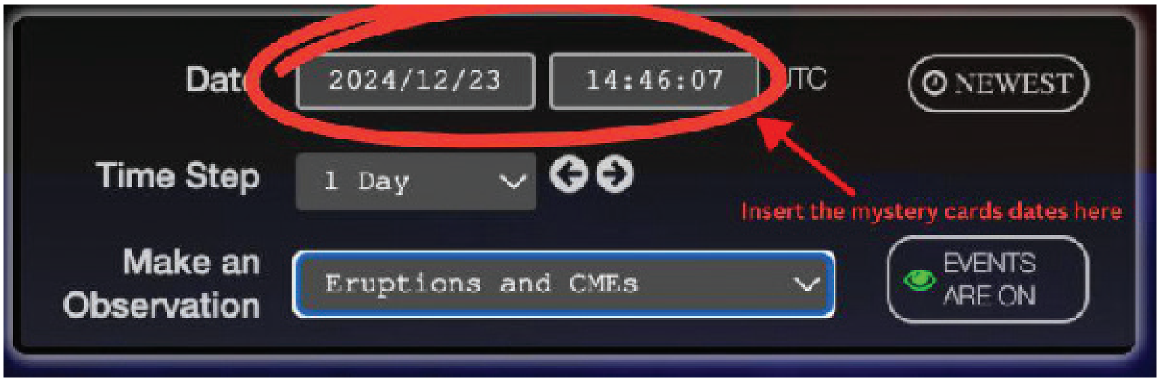
Activity Procedure (Daily Viewing):

1. Explain that students will use the Helioviewer to examine data collected by NASA instruments.
2. Working in pairs, students will open the Helioviewer and observe the Sun's current activity. Ask students what they notice about the image of the Sun?
3. Allow a few minutes for the students to explore the site. Under "Make an Observation," they can click through the dropdown menu to use different filters to view different features and physical properties of the Sun.
4. Instruct students to select "Sunspots" in the "Make an Observation" dropdown menu. Encourage them to sketch the location of the sunspots on their worksheet.
5. Encourage students to examine the data they collected with the Helioviewer. Did they notice anything on or near the sunspots?



Activity Procedure (Past Data with Mystery Cards):

1. Explain that the Helioviewer can display historic data as well as current data.
2. Challenge students to enter the dates of the mysterious events on the mystery cards. into the "Date" box on the Helioviewer. What do they notice about the Sun's activity?



3. As students explore the different dates, ask them if they notice any patterns.
4. Encourage students to share their discoveries or theories as to what is causing the mysterious events.
5. Explain that they will gather more data and information throughout the program, and that it's ok to be uncertain about their theories.
6. Add theories and questions to the solar mystery chart paper.

Activity Procedure (Final Day):

1. Review collected data from the Helioviewer.
2. Connect the data to the mysterious events.

Extension Ideas:

If students are confident with the Helioviewer and would like to use advanced features, they can visit the *www.helioviewer.org* webpage.

Important Activity Information

The Helioviewer contains data from 1950-Present. Some of the dates on the mystery cards are older than 1950, so students will not be able to view data from those dates. Be sure to give students a heads up about this.

Background Science:

The student Helioviewer is an interactive tool the learner can use to access NASA's data about the Sun and its features including solar flares, magnetic fields, sunspots, and CMEs. The data are collected by spacecraft and solar telescopes such as NASA's Solar Dynamic Observatory (SDO), the joint ESA/NASA solar and Heliospheric Observatory (SOHO) and others. The Helioviewer can be used to study the Sun's activities currently or dating back to a few decades in the past. The data can help scientists study the Sun's solar cycle and predict solar storms that can affect our communication, cause power outages, and auroras on Earth.

Additional Resources:

If you have a Sunspotter at your museum or organization you can use it to observe the Sun and the sunspots as well. See example here: *https://www.fishersci.com/shop/products/sun-spotter-telescope/S01384*

If you are interested in building your own sunspotter, check out our *High School Solar Science curriculum* and click on "Session 2"

Sources:

https://science.nasa.gov/get-involved/citizen-science/be-a-solar-active-region-spotter/

https://science.nasa.gov/learn/heat/resource/student-helioviewer-solar-data-interactive/#:~:text=A%20student%2Dfriendly%20interactive%20with,fields%2C%20sunspots%2C%20and%20CMEs.

Session 3: Paper Plate Solar System Model

Activity Overview:

Students will be able to describe and demonstrate how the Moon and Earth interact as they orbit the Sun.

Duration: 45 min

Preparation:

- Create an example
- 2. Pre-cut the paper strips. You'll need one 8-inch and one 16-inch strip per student (which can also be two 8-inch strips taped together)

Key Terms:

Orbit: A repeating ellipse-shaped path that one object in space follows around another object in space.

Planet: To be considered a planet in our solar system, a celestial object must do three things: Orbit around the Sun, have enough mass that gravity makes it nearly spherical, and clear away other objects in its orbit.

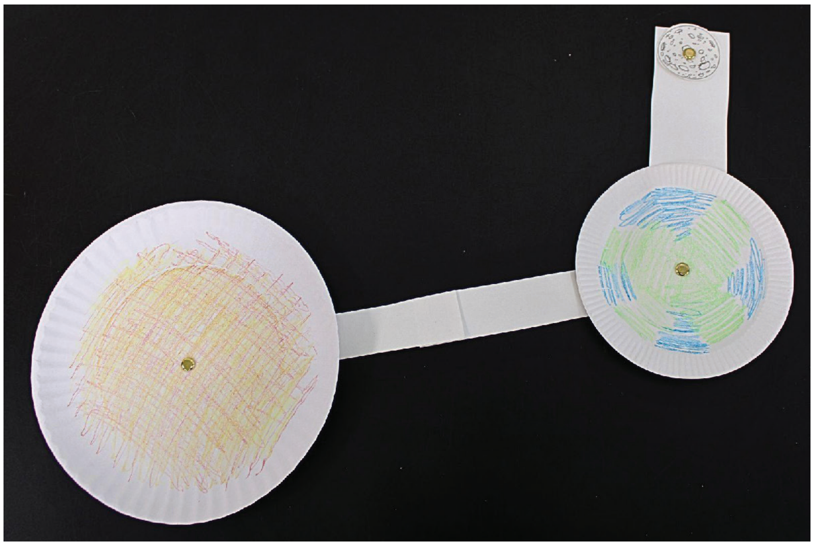
Star: A hot, glowing ball of gas.

Sun: The large star at the center of our solar system.

Satellite: An object that moves (orbits) around another object.

Moon: Earth's only natural satellite.

Solar Eclipse: When the Moon passes between the Sun and the Earth.



Materials:

- Large paper plates (~9 inches)
- Small paper plates (~6 inches)
- *Moon template* printed on cardstock
- Coloring supplies (ex: crayons, markers, etc)
- Scissors
- Brass fasteners
- Push pin
- Long paper strips (~16in; ~ ½ in thick)
- Short paper strips (~8in; ~ ½ in thick)
- *Optional:* hole punch
- *Optional:* Something to trace a small circle with

Useful Tip:
Some students may struggle with fine motor skills and will need help pushing the brass fastener through the paper plates.

Activity Procedure:

1. Introduce the activity by explaining that each student is going to make their own model of the Earth, Sun, and Moon. This model will demonstrate how the Moon moves around the Earth, and how the Earth moves around the Sun.
2. Show them an example and explain that there is a term used to describe how objects move around each other in space. Guide students towards identifying the terms “orbit” and “satellite”.
3. Distribute a large paper plate to each student, explaining that it is going to be the Sun. Let them color and decorate the Sun. They can make it look like our Sun, or invent their own sun.
4. Distribute a small paper plate to each student, explaining that this is going to be the Earth. Let them color and decorate the Earth. They can model it as our Earth, or invent a planet.
5. Lastly, distribute another small plate to each student and explain that it is going to be the Moon. They can model it as our Moon or create their own moon. Let them color and decorate the moon.
6. Use a pushpin to poke a hole through the center of each template (sun, moon, planet)
7. Poke a brass fastener through the hole in the **planet**. Attach it to the short strip of paper
8. Use another brass fastener to attach the **moon** to the other end of the short strip (The order is important! You need to attach the planet first for the eclipse effect)
9. Using the long strip of paper, use a brass fastener to attach the **planet** to one end and the **sun** to the other
10. Check your work! The **planet** should rotate around the **sun**, and the **moon** should rotate around the planet. The **moon** should come between the planet and sun when it rotates
11. Encourage students to move the celestial bodies around. Ask what they notice happening?
12. Demonstrate how an eclipse occurs by aligning the moon, sun, and planet in a straight line (in this order)
13. Optional: Let students present or share about the solar system they created

Extension Ideas:

If students designed their own solar system, let them share about what they created and why. Encourage them to think about what they know about celestial bodies. Ex: If the sun is blue, what would that mean? How would that impact their planet?

Background Science:

Due to the pull of gravity, the Earth orbits around the Sun, while the Moon orbits around Earth. Even though our Sun is approximately 93 million miles (150 million kilometers) away, we feel its effects every day and depend on it for light and heat. Occasionally, the Moon passes between the Sun and Earth, and blocks the light of the Sun from reaching the Earth. This phenomenon, called a **solar eclipse**, can make it (briefly) dark on Earth during the middle of the day. When the Moon blocks part of the Sun, it’s called a **partial solar eclipse**, and when it blocks the entire Sun, it’s called a **total solar eclipse**.

Sources:

https://spaceplace.nasa.gov/all-about-the-sun/en/

https://spaceplace.nasa.gov/eclipse-snap/en/)

Session 4: Layers of the Sun

Activity Overview:

Students will use clay and clay tools to create a 3D model of the Sun that depicts the Sun's layers.

Duration: 40 min

Preparation:

- Create an example of a complete model so that students can visualize the activity
- For each layer, display a corresponding slide that includes
  - An image of the layer
  - The name of the layer
  - A one-sentence description of the layer

Materials:

- Play-doh, Model Magic or modeling clay of a variety of colors
- Clay tools (rollers, etc)
- Plastic knife
- Paper plates
- Information *Slides* (22-29)

Key Terms:

Core: The hot and dense center of the Sun where energy is generated through nuclear reactions.

Nuclear Fusion: Occurs when the pressures and temperatures in the core of a star cause hydrogen atoms to collide with so much force that they fuse into helium. Fusion reactions release energy and create additional particles in chain reactions that can steadily release energy for billions of years.

Radiative Zone: The layer of the Sun where energy is slowly transported outwards as radiation.

Radiation: The electromagnetic radiation emitted by the Sun (for example, light).

Convective Zone: The layer of the Sun where energy moves outwards through convection currents (bulk transport of matter).

Convection: A type of energy transport that generates magnetic fields as hot bubbles of gas rise towards the surface while cooler bubbles of gas fall towards the core (think of a boiling pot of water on a stove).

Photosphere: The deepest layer of the Sun that is directly visible and that emits the most visible light. This is what we see from the earth using special Solar telescopes or Sunspotters so that we can safely look at images of the Sun with our eyes.

Chromosphere: A thin layer of the Sun that is made of plasma and appears red, which becomes visible during a solar eclipse.

Plasma: Extremely hot, ionized gas that constantly moves and generates magnetic forces and radiation.

Corona: The outermost layer of the Sun that is visible during a solar eclipse, the corona consists of million-degree gas that emits X-rays.

Useful Tip:

- If students with sensory differences dislike touching Play-doh, it can be helpful to either:
  - Have disposable gloves available
  - Partner them with a student who doesn't mind touching Play-doh

- Print the visual guide as an option for students to follow along at their own pace. [Layers of the Sun *Visual Guide pdf*]

Activity Procedure:

1. Have students select 6 contrasting Play-doh colors. This is important because each layer of the Sun needs to be identifiable.
2. Tell students to choose their first color and roll it into a ball. The will represent the **core**, which is the center of the Sun. The **core** is extremely hot and dense, and is where **nuclear fusion** occurs.
3. Tell students to choose their second color. Flatten this dough on the table using two hands or a roller. Place the core in the center of the flattened dough, and wrap the flattened dough around the core. They can roll their dough ball on the table to smooth it out. They should have a slightly bigger dough ball with only the second color showing. Explain that this layer represents the **radiative zone**, which is where energy is transported via radiation (light energy).
4. Have students select their third color, and repeat step 3. They should flatten this layer and wrap it around the ball. Explain that the third layer is the **convective zone**. This zone is where energy is moved via **convection** (bulk matter transport).
5. Instruct students to create a fourth layer using the same method. Explain that the fourth layer is the **photosphere**, which is the visible layer of the Sun.
6. Repeat the same process to create the fifth layer, which is the **chromosphere**. Explain that the **chromosphere** is shaped by magnetic field lines that work to hold in the Sun's **plasma** (ionized gas).
7. Lastly, have the students create the sixth and final layer, the **corona**. Explain that the **corona** is the layer of the Sun that is visible during the eclipse.
8. By now, students should have a large ball of dough that contains 6 layers of different colors. This represents our Sun.
9. Give students a plastic knife and instruct them to cut their Sun in half, revealing the different layers.
10. Now that they can see each layer, go back and name each layer, reminding them that each layer of Play-doh represents a layer of the Sun. Explain that knowing the different layers will help them with tracking information and solving the mysteries.

Background Science:

The Sun is composed of six distinct layers. The Sun's energy is produced in its **core**, then moves outwards through the other layers (**radiative zone, convective zone, photosphere, chromosphere, corona**).

The **core** is the central region of the Sun. It is also the hottest region of the Sun. In the **core**, the Sun's energy is produced via **nuclear fusion**, where hydrogen fuses to form helium. This process produces a lot of energy, and is what ultimately provides us with heat and light.

Leaving the **core**, the energy first reaches the **radiative zone**, where the energy moves outward via **radiation**. It takes more than 177,000 years for energy to move through the radiative zone due to interactions between the solar plasma and light.

Next, it reaches the **convective zone**, where **convection** currents take over and physically transport the Sun's energy to the photosphere. This is the last layer of the inner zone of the Sun.

Next, energy reaches the **photosphere**, which is the first layer of the outer zone of the Sun, which is also known as the Sun's atmosphere. The photosphere is the visible part of the Sun (i.e., the layer from which we see light).

Above the photosphere is an irregular layer called the **chromosphere**, which is made of a thin layer of plasma. Magnetic field lines on this layer help hold the Sun's plasma in place, even though it can break out and leave the surface during coronal mass ejections.

The last layer is the **corona**, which can only be viewed by the human eye during a solar eclipse. X-rays from the corona can be seen from the Sun at other times, using special X-ray detectors on satellites or rockets that are launched above the Earth's atmosphere

Additional Resources:

Information slides and add "beginning at slide 22"

How to Make a Sun Model: *https://www.twinscience.com/en/blog/how-to-make-a-sun-model/*

Sources:

https://spaceplace.nasa.gov/sun-heat/en/#:~:text=This%20process%E2%80%94called%20nuclear%20fusion,area%20called%20the%20convective%20zone.

https://solarsystem.nasa.gov/genesismission/science/module4_solarmax/structured_sun.html

https://solarscience.msfc.nasa.gov/interior.shtml

https://www.nasa.gov/image-article/layers-of-sun/#:~:text=The%20inner%20layers%20are%20the,Transition%20Region%20and%20the%20Corona.

https://www.nasa.gov/image-article/anatomy-of-sun/

https://www.nasa.gov/image-article/sun/

Session 5: Direct vs. Indirect Light

Activity Overview:

Students will explore how the Earth's tilted axis causes different seasons. Using a model of the Earth and a flashlight, students will explore how direct sunlight transfers more energy than indirect sunlight

Duration: 20-30 min

Preparation:

- Plan to run the activity in a dimly lit area. This will ensure that the light from the flashlight will be visible.
- Inflate the inflatable Earth globes ahead of time.

Materials:

- *Earth, Sun, and Moon model* (this can also be created using Activity 3: Paper Plate Solar System Model)
- *1 tilted globe with a stand*
- 8 flashlights
- 8 globes or *inflatable Earth globes*
- *Sticky note flags*

Key Terms:

Axis: An imaginary straight line that runs through the Earth from "top" to "bottom." The Earth spins around its ***rotation axis***.

Tilt: Long ago, a large object crashed into the Earth and knocked it off-kilter. As a result, the Earth's rotation axis is tilted 23.5 degrees. This tilt is what causes the seasons.

Orbit: A repeating ellipse-shaped path that one object in space takes around another object in space.

Equinox: An event that occurs twice a year when the Sun crosses the Earth's equator. When this occurs, the lengths of day and night are approximately equal.

Solstice: An event that occurs twice a year when the Sun reaches its highest or lowest point in the sky at noon. This causes the longest or shortest daylight hours of the year (in opposite hemispheres).

Equator: An imaginary circle around the Earth that divides it into two halves

Hemisphere: The top and bottom halves of the Earth divided by the equator. The top half is the Northern Hemisphere and the bottom half is the Southern Hemisphere.

Direct Sunlight: Sunlight that is concentrated on a small surface area because the beam of light hits the Earth head on.

Indirect Sunlight: Sunlight that is spread out over a larger surface area because the beam of light hits the Earth at a tilted angle.

Useful Tip:
Some participants may find bright light or sudden changes in light overwhelming. Prepare students for this ahead of time, and remind them they can look away or close their eyes if needed. It may help to have sunglasses available. Some students may want a heads-up before the flashlight is utilized.

Activity Procedure:

1. Begin by asking students the following questions:
   a. What causes our seasons?
   b. Can you name the different seasons?
   c. Why do you think it's hotter in the summer and colder in the winter?
2. Elicit some answers and show Image 1. Explain that they are going to explore what causes the different seasons.
3. Use the model of the Sun, Earth, and Moon to show the position of the Sun in relation to the Earth, and demonstrate how the Earth revolves around the Sun. Ask students what they notice about the Earth?

4. Demonstrate that the Earth is tilted approximately 23.5 degrees by showing the globe on an axis. Explain that the Earth remains tilted throughout the year as it orbits around the Sun. (Show Image 2.)
5. Explain that the Earth's tilt causes the Sun to shine directly or indirectly at the Earth at different times of the year.
6. Using the globe, show students how the Earth is divided by an imaginary line called the equator into two halves called the Northern and Southern Hemispheres

7. Point to where your city is located on the globe. Place a marker such as a sticky note to point where you are on the globe. This example points to New York City in the Northern Hemisphere.
8. Explain that you will demonstrate how sunlight is distributed (for this example- in New York City) during the four seasons. Explain that a flashlight will represent the Sun.

a. During Winter, the Northern Hemisphere is tilted away from the Sun, receiving less intense sunlight as the light spreads out over a larger area. We call this **Indirect Light**. Shine the flashlight towards the globe and notice how light spreads out. Compare the light at the center of the beam (which should be on the Southern Hemisphere) with the light that reaches the Northern Hemisphere

b. During Spring and Fall, both hemispheres receive equal amounts of sunlight as the light has the same intensity. Shine the flashlight on the Equator. Most of the concentrated light should be on the Equator, we call this **Direct Light**. Compare the light that reaches points in the Northern and Southern Hemispheres that are the same distance from the equator. The Indirect light should be the same at these places because the angle between the center of the flashlight beam to each point is the same for each hemisphere.

c. During Summer, the Northern Hemisphere is tilted towards the Sun receiving more intense sunlight (**Direct Light)**. Shine the flashlight towards the globe and notice how the light is concentrated on the Northern Hemisphere.

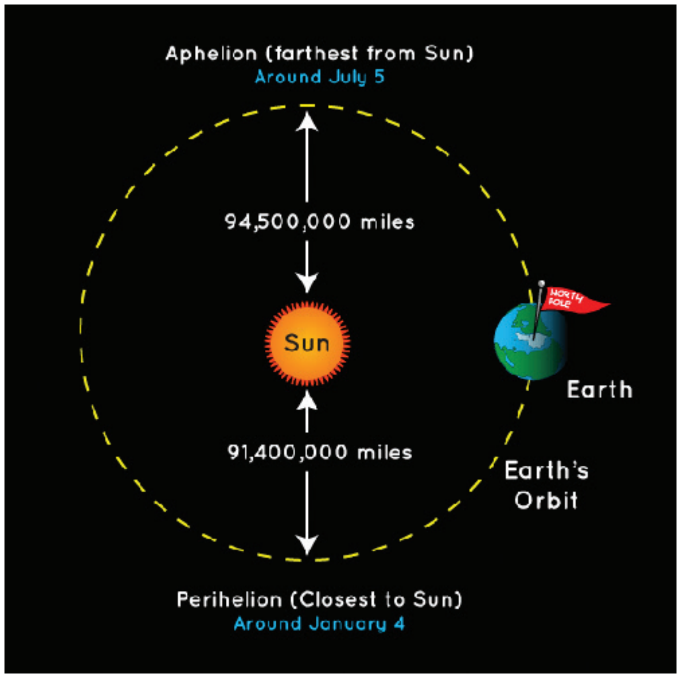
9. Distribute flashlights and an Earth beach ball to groups of students. Encourage them to take turns shining the flashlight on the Earth beach ball to demonstrate direct and indirect sunlight on the Northern Hemisphere, which will simulate the different seasons. Repeat and follow steps 8 to guide students on shining the flashlight on the globe.

10. Allow participants to explore different parts of the world at different times of the year. For example, when it is summer in the Northern Hemisphere, what season do countries in the Southern Hemisphere experience?

Background Science:

The energy received on any portion of the Earth is a fraction of the total energy that comes from the Sun. Because the Earth is a sphere and is tilted, areas tilted away from the Sun receive less intense (indirect) sunlight, which is sunlight that is spread out over a larger surface area. Areas that are directly facing the Sun receive more intense (direct) sunlight, which in turn causes warmer weather. Whichever hemisphere is facing towards the sun during the course of the Earth's orbit will receive more of the sun's energy throughout the day. This happens during summer time in New York, thus making our days hotter. At the same time, places in the southern hemisphere will receive less intense sunlight thus making the days feel colder, and will be experiencing winter.

Additional Resources:



Misconconception Alert:

Students may think the Earth is closer to the Sun during summer time in New York but in fact we are actually closer to the Sun during the winter time. Use the image above to show how far away the Earth actually is during the months of July and January.

Sources:

https://spaceplace.nasa.gov/seasons/en/.

https://earthobservatory.nasa.gov/blogs/eokids/wp-content/uploads/sites/6/2019/04/16_SunSeasons-508.pdf

Session 6: Magnetic Fields

Activity Overview:

Students will use a tool called a **magnetometer** to explore the difference between the Sun's magnetic field and the Earth's.

Duration: 30 min

Preparation:

- Use an x-acto knife or blade to make an incision in the foam Earth model. Insert one bar magnet so it is aligned with the Earth's poles.

Handmade magnetometer visual guide:

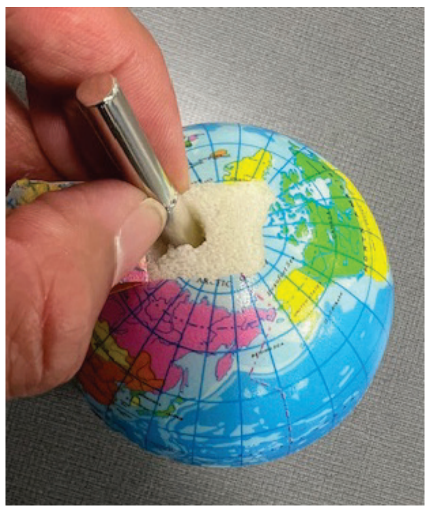
Bar shaped magnets. Can be combined if needed.

Materials:

- Foam *Earth models*
- Handmade magnetometer
- Bar shaped rare earth magnets
- Standard circle magnets
- Large bowls
- Tape
- Paperclips
- Pencil
- Push pin

Put a piece of tape at the pole

Make an incision in the foam Earth model



Insert one bar magnet

- To create a model of the Sun's magnetic field, tape the circle magnets at random points inside your large mixing bowl (if your bowl is metal, you can just let the magnets use their magnetism to stick without the tape). The Sun's magnetic field shifts and changes constantly, creating random spots of stronger magnetism, so there really is no set pattern or number of magnets you need to use. When you're satisfied with the number and placement of magnets on your Sun, flip the bowl over face down so that it creates a dome with the magnets hidden on the underside.

- Create a magnetometer using a pencil, paperclip, and pen
  - Stick the pin in the pencil eraser
  - Bend a paperclip around the pin so there are two "wings"

Handmade Magnetometer

Key Terms:

Magnet: A material or object that produces a magnetic field. This field is invisible, but produces a force called magnetism. Ferromagnetic materials such as iron can be magnetized permanently, creating areas where the field is stronger. These areas are called **poles**: like poles repel each other while opposite poles attract each other.

Magnetic Field: The area around a magnet that has magnetic force (strength and direction).

North Pole: On Earth, the North Pole is a South magnetic pole. It is attracted to the North pole of a magnet.

South Pole: On Earth, the South Pole is a North magnetic pole. It is attracted to the South pole of a magnet.

Magnetometer: A device that measures the strength or direction of a magnetic field.

Sunspots Large, dark regions on the Sun's surface that are caused by increases in the Sun's magnetic field, and are cooler than the solar surface.

Useful Tip:
Group work can be stressful for certain types of learners. While working together is encouraged, prepare to have extra supplies for those who choose to work alone.

Activity Procedure:

1. Begin by asking students what they already know about magnets.
2. Hand out the Earth models and magnetometers. Ask students to use the magnetometer to explore where the Earth model has the strongest magnetism.
3. Make sure students understand that the magnetometer feels the strongest attraction at the poles (the top and bottom of the model). This is the same on our planet. The Earth is a giant magnet, and the magnetism is the strongest at the top and bottom of the planet (the North and South poles.)
4. Distribute the Sun models. Ask students to use the magnetometers to explore where the Sun has the strongest magnetism.
5. Students should notice that strong areas of attraction are found in random spots on the Sun (and not at the poles). This is a model of how our Sun's magnetism works.

Background Science:

Magnets are objects that create a magnetic field. This field has a North pole and a South pole, which are the strongest parts of the field. Some magnets occur naturally, and others can be created using electricity. Everything in the world is made of atoms, and atoms are made of charged particles (protons and electrons). Electrons (which are negatively charged), orbit around an atom's nucleus (center), creating a small magnetic field, and also have intrinsic magnetism called **spin** (that can be visualized as the electron spinning around its own axis. However, spin is really a quantum property.) In most materials, electrons travel in pairs that spin in opposite directions, which essentially cancels out the magnetic field. This is why most materials aren't magnetic, despite being made of charged particles. However, certain materials have unpaired electrons that spin in the same direction, keeping the magnetic field intact. For example, iron has four unpaired electrons that can spin in the same direction and align along North-South lines, creating a magnetic field which is persistent.

The Earth's magnetic field comes from its molten core. The lead in the core moves and creates magnetism. The magnetic field on Earth is shaped like a bar magnet, where the magnetism is the strongest at the top and bottom on the planet. On occasion, the North and South poles flip. The last pole reversal occurred approximately 770,000 years ago.

The Sun's magnetic field works very differently than the Earth's. It regularly shifts and changes, with the strongest points appearing and disappearing across the surface. NASA scientists do not know exactly where the Sun's magnetic field is created. The Sun is made of plasma, which is full of charged particles. As these particles move, they continuously create magnetic fields. Scientists can study these shifting magnetic fields with EUV (Extreme Ultraviolet) images as well as X-ray images.

Sources:

https://www.nasa.gov/science-research/heliophysics/nasa-understanding-the-magnetic-sun/

https://spacemath.gsfc.nasa.gov/magnetism/magnetism.html#:~:text=The%20answer%20has%20to%20do,call%20these%20invisible%20influences%20FIELDS.

https://www.nasa.gov/wp-content/uploads/2020/08/parent_activity_manual_-_its_magnetic_v1.0.pdf?emrc=1288de

Session 7: Making the Invisible Visible

Activity Overview:

Students will create bracelets using beads that change color when exposed to ultraviolet (UV) light. Students will understand that even though humans can't see UV light, it still affects us. Additionally, students will explore how certain telescopes can detect UV light, which allows scientists to learn more about the Sun.

Duration: 45 min

Preparation:

- Print out copies of the electromagnetic spectrum, images taken by the Hubble Telescope, and *worksheets*.

Materials:

- UV Beads
  Where to Purchase:
  Carolina Biological
  Arbor Scientific
- *Black light or UV Flashlight*
- Pipe cleaners
- Regular plastic beads
- Images of the Electromagnetic Spectrum printout
- *Worksheet* to test UV beads printout
- Pencil

Key Terms:

Electromagnetic Spectrum: Electromagnetic energy travels in waves of many lengths. These waves exist on a spectrum from short waves (such as gamma rays) to long waves (such as radio waves). NASA has instruments capable of detecting different parts of the spectrum, covering the entire range. We can see visible light waves, which are about 400 to 700 nanometers (a nanometer is 1 billionth of a meter!)

Wavelength: The length of a single wave. Long waves (like radio waves) can range from meters up through kilometers. Short waves (like X-rays and gamma rays) have wavelengths ranging from nanometers to as short as femtometers.

Ultraviolet (UV): A type of light with shorter wavelengths than visible light. UV waves are invisible to humans, but can be harmful (e.g., causing sunburn). Near-ultraviolet light has wavelengths very "near" to violet visible light, but slightly shorter.

Infrared waves: Light waves slightly longer than visible light waves. They range from near-infrared that is used in remote controls, to far-infrared which can be sensed as heat. Near-infrared light has wavelengths very "near" to red visible light, but slightly longer.

Solar Dynamics Observatory (SDO): This spacecraft was launched in February 2010. Its purpose is to study the Sun and explore how solar activity is created, and how it drives space weather.

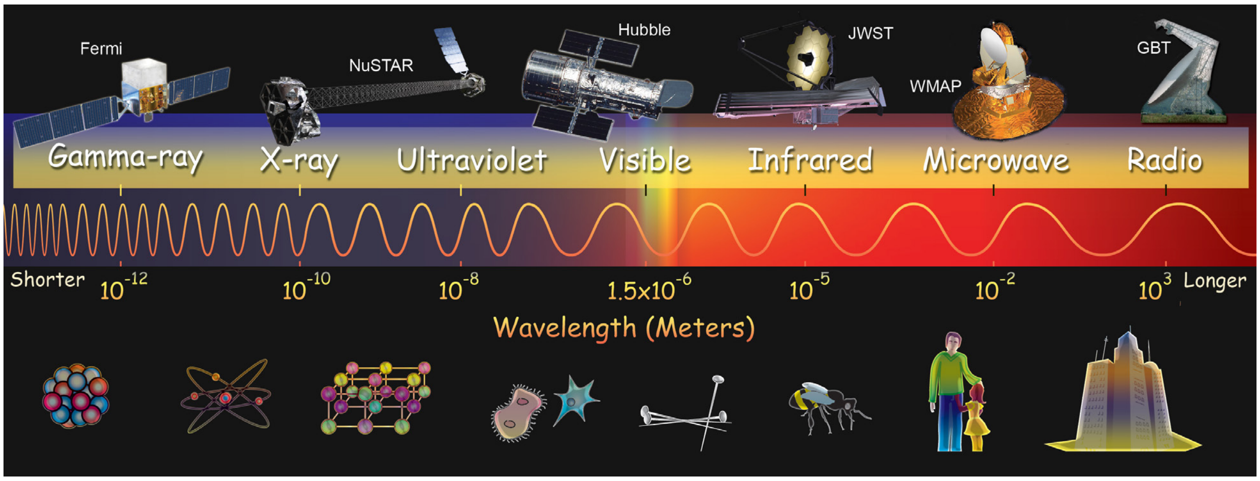
Hubble Space Telescope: This space telescope was launched on April 24, 1990 to Earth's low orbit to explore the universe in visible, ultraviolet, and infrared wavelengths.

White Light: Another term for visible light. This contains all the colors of the visible light spectrum, and can be split into individual colors with a spectrometer or prism. Typical lighting sources use white light.

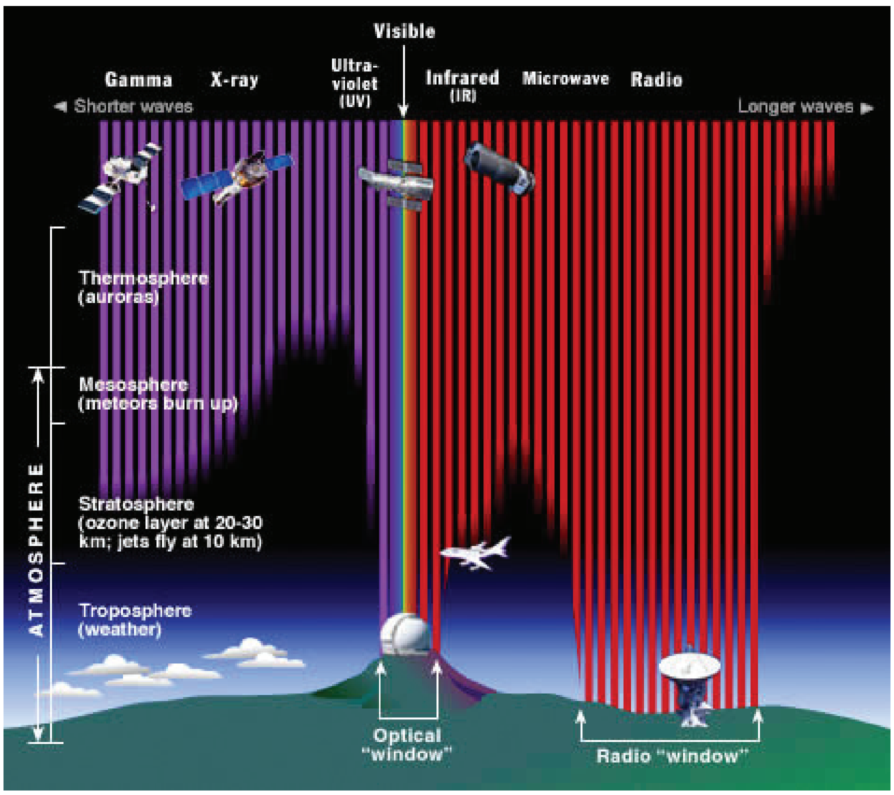
Useful Tip:
The light might be too bright for students with light sensitivity. Prepare them in advance for this possibility, and explain they can look away or close their eyes if they want. You may also want to provide sunglasses.

Activity Procedure:

1. Show students the image of the Electromagnetic Spectrum and explain that ultraviolet light has shorter wavelengths than visible light. Explain that our eyes cannot detect this wavelength, even though some insects can (like bumblebees).

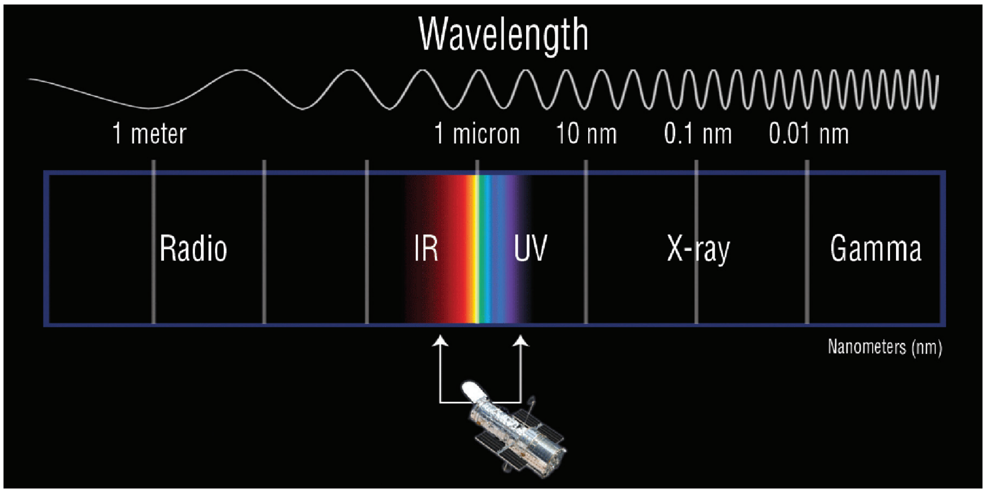


2. Show students the image of the Sun from the SDO and explain that special telescopes can detect UV waves and use them to create an image of the Sun for astronomers and scientists to study.



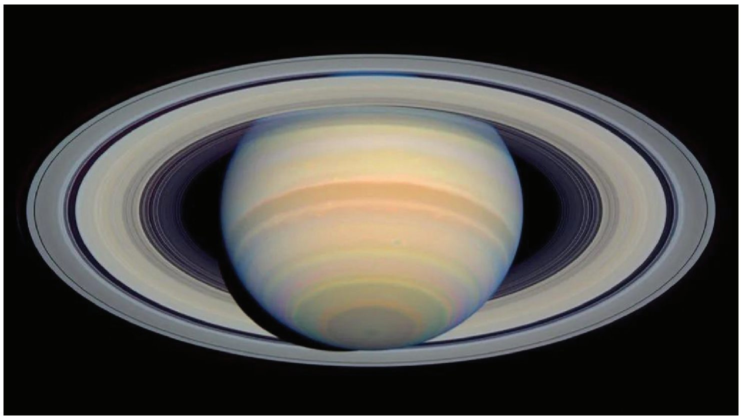
3. Introduce the UV beads and explain that the beads will appear white under white light.

4. Introduce the Hubble Space Telescope to participants by showing the image of Hubble and the range of wavelengths it can detect.

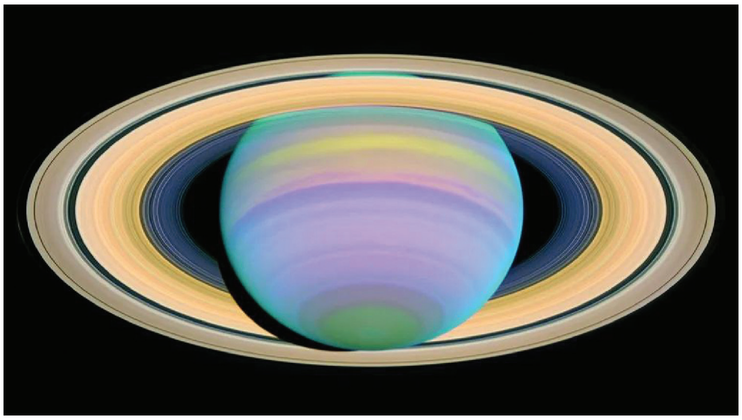


https://science.nasa.gov/mission/hubble/science/science-behind-the-discoveries/wavelengths/

5. Hand out the images of the Eagle Nebula and Saturn from the Hubble Space Telescope taken using Visible, Infrared, and Ultraviolet light. Ask the participants to compare the images taken by the telescope

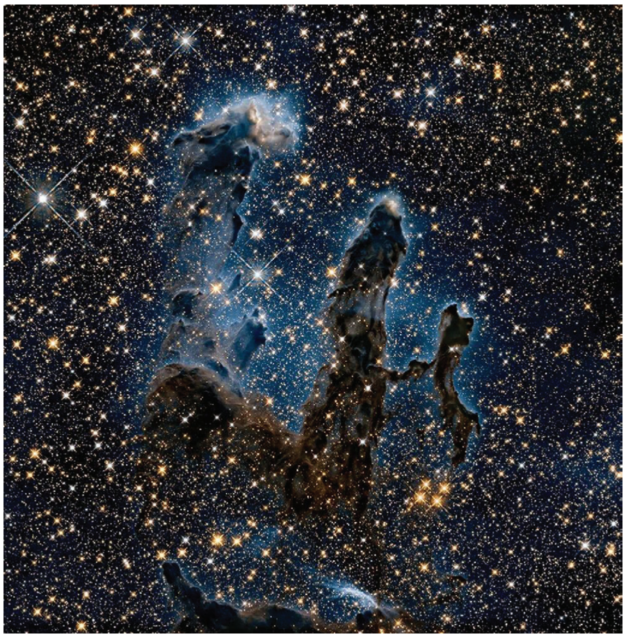


Saturn using visible light



Saturn using ultraviolet light

Eagle Nebula using visible light



Eagle Nebula using infrared light

https://science.nasa.gov/mission/hubble/science/science-behind-the-discoveries/wavelengths/

6. Distribute 6 UV beads and 6 regular beads to each student.
7. Encourage students to use the UV flashlight to shine light directly on the beads. Observe what happens to the color of the beads.
8. Explain that students can make their own wearable UV detectors by making bracelets with the UV beads.
9. Give each student a pipe cleaner and have them thread the beads through it. They can create patterns or design their bracelets. Once finished, they can twist or tie the ends of their pipe cleaner.
10. Hand out the worksheet and let students test out their UV bead bracelets when shielded by different materials. Using the UV flashlight, place the beads either: behind a piece of paper, behind sunglasses, or in a ziplock bag with different types of sunscreen on the outside of the bag.

Background Science:

The Sun emits many different wavelengths of light, while our eyes can only detect visible light. However, telescopes allow us to see a wider range of wavelengths, including ultraviolet (UV) light. Ultraviolet light waves are shorter than visible light waves. Even though we cannot see UV light, it affects our health. While UV light can cause sunburn and other health issues, it also provides us with necessary vitamin D. Fortunately, most harmful UV rays are absorbed by the ozone layer in Earth's atmosphere.

UV detecting beads are a great (and low cost!) way to detect the strength of UV rays. Some days UV rays are brighter than others, and the beads can help tell us how much protection we need from the Sun. When not in UV light, the beads will appear clear. When exposed to UV light, the beads will change color, with brighter colors indicating higher levels of UV. The polyethylene beads are embedded with a chemical called a spirocompound, which reacts with UV light. This reaction causes a molecule to break and rotate, changing the way light is absorbed and reflected. The light reflects back to our eyes at a longer wavelength, which luckily is in the visible range.

The Hubble Space Telescope orbits above the Earth's atmosphere, where it collects UV radiation from space. It collects 40,0000 times more light than the human eye which allows astronomers to study details of faint objects in space. The Hubble Space Telescope has mirrors to collect light and instruments that include cameras and spectrographs to interpret the collected light. The cameras can see different kinds of light: near-ultraviolet, visible, and near-infrared while the spectrograph splits the light into its individual wavelengths. Ultraviolet light comes from the hottest, largest, and youngest stars. Astronomers observe ultraviolet light to see which galaxies are forming stars and where the stars are forming within those galaxies. Ultraviolet observations can also help us determine the composition of the atmospheres of planets beyond our solar system.

Sources:

https://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/background-spectroscopy.html

https://science.nasa.gov/ems/10_ultravioletwaves/

https://science.nasa.gov/mission/sdo/

https://www.acs.org/content/dam/acsorg/education/outreach/kidszone/uv-detecting-wristband.pdf

https://science.nasa.gov/learn/heat/resource/experimenting-with-uv-sensitive-beads/

https://multiverse.ssl.berkeley.edu/FiveStars

Session 8: Aurora Art

Activity Overview:

Students will use oil pastels and blending techniques to create images of the aurora borealis, which is represented in many of the mystery cards. This activity is intended to create a visual representation of the aurora for students who have never seen one, and showcase how science and art can combine.

Duration: 1 hr

Materials:

- Oil pastels
- Paper (cut in half sheets)
- Masking tape
- White paint
- Toothpicks
- Pencil
- Bowls for paint
- Paper towels or blending sticks

Preparation:

- This guide will demonstrate how to create a specific image, but there are many ways to create aurora art (see Extension Ideas).
- It may be helpful to watch online tutorials (search for: aurora pastel drawing) to better understand the technique and learn a diverse range of methods and ideas.

Key Terms:

Aurora Borealis: A natural display of colorful, dancing light that typically appears near the North Pole or at northern latitudes. Also called the Northern Lights, auroras are caused by solar storms and occur more frequently (and extend further south) when the Sun is active. A similar phenomenon occurs near the South Pole, and is called ***Aurora Australis***.

Coronal Mass Ejections: An event where the Sun emits more charged particles and energy than usual, accompanied by mass loss from the solar surface. These events can cause an increase in the light seen from the auroras.

Blending: The art technique of smoothing colors together to create a gentle transition

Facilitation Tips:

Inform students that everyone's picture will look a little different, and that's ok. If they want to deviate from the instructions to create their own art, that is ok. Just make sure they are comfortable with a different outcome if they choose to get creative.

Useful Tip:

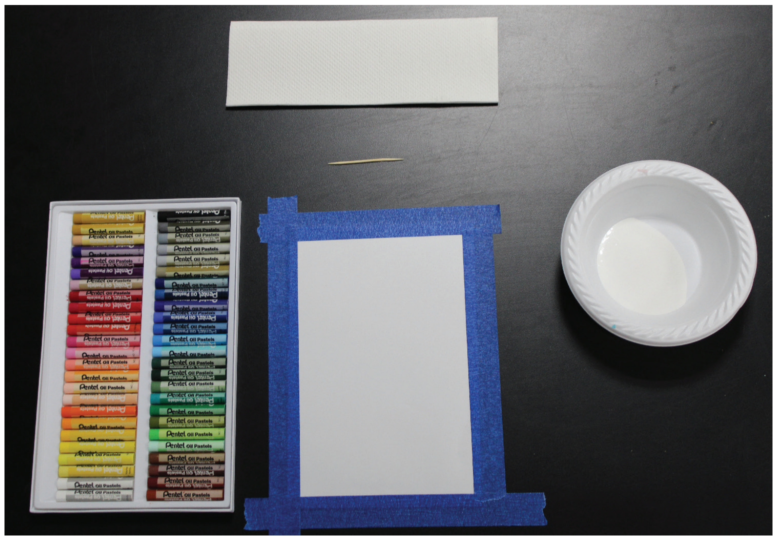
This activity is very open-ended, which is helpful for some students and overwhelming for others. Some students might feel stress or pressure for their art to look like the example, especially if those students struggle with fine motor skills and/or emotional regulation. It is helpful to remind students that the example is just a suggestion, and that art is meant to be personalized and unique to the artist. Encourage them to be open-minded about their final design, and have patience while working on the activity.

If needed, let students take a break from the activity if they are frustrated. If they aren't able to regulate their emotions during the activity, it may be helpful to let them finish the activity later in the day. Additionally, having extra supplies on hand is helpful if students want to start over.

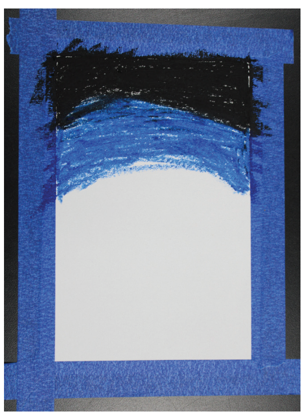
Activity Procedure:

1. Use masking tape to secure the paper to the table and create a ½" border on all four sides

2. Select 3-4 colors to create the aurora. Since auroras come in many colors, students can get creative with the colors they choose. However, best results will include one dark color (black or navy) and 3 lighter shades



3. Using the dark color, color the top 1/5th of the paper. Make sure students understand that it doesn't need to be a straight line, waves and unevenness are more natural



4. Choose the second darkest color and color in the next 1/5th of the paper

5. Choose the second lightest color and color in the next 1/5th the paper.

6. Choose the lightest color, and color the next 1/5th of the paper.

7. Use the lightest color to add some “glow” effect between the last two colors.

8. Time to blend! Fold a paper towel firmly in a triangle shape. It is recommended to start with the lightest color and blend upward for the best glow.

9. Use the darkest color to create a jagged line between the white space and the lightest color. This is the mountain top, and they can customize the mountains to look however they want. Color in the remaining white space with same dark color.

10. Use a pencil to finish the edges of the mountains

11. Use a toothpick dipped in white paint to dot “stars” in the sky. These can be random or look like constellations.

12. Carefully and slowly remove the masking tape. The picture is now complete! Make sure students sign their names.

Troubleshooting:

When you peel the tape away, if you find that it's tearing the paper or leaving residue behind you can use a hairdryer to warm up the tape's glue. This will make it easier to separate the tape from the paper.

Extension Ideas:

This project can be done in a variety of ways. The main goal is to blend colors in the background, and use a solid shape or structure in the foreground. Other space-themed backgrounds could be galaxies, celestial objects, and sunrises/sunsets

Background Science:

The aurora borealis (also known as the northern lights), is caused by free electrons that interact with atoms in the Earth's atmosphere and make the atmosphere glow. In addition to providing the Earth with heat and light, the Sun also sends charged particles to Earth. While Earth's atmosphere and magnetic field in space (called the magnetosphere) protects us from these solar particles, the interaction between these particles and the magnetosphere generates electricity. It is this electricity, or electrical current, that powers the northern lights. The types of coronal mass ejections that interact with Earth's magnetic field determine where and how bright the aurora borealis can be. Sometimes it will brighten and move to more southern states, such as California, Wyoming, Texas, or South Carolina. Other times, they remain mostly visible to people in northern states, such as Alaska, Washington, Vermont, and Maine.

The different colors we see in the aurora are a result of how the electricity generated within the Earth's magnetosphere interacts with the upper atmosphere, located 60 miles to 300 miles above Earth's surface. The electricity that makes the aurora borealis glow is made up of very rapidly moving electrons. When these electrons collide with the oxygen in the upper atmosphere, the gas glows in green and red light. When these electrons are energized by the solar particle's interaction with Earth's magnetic field, they move even faster and make it down to 60 miles above Earth's surface. At this height, the electrons encounter nitrogen gas, which glows in red and blue, making it look like a purple glow.

Sources:

https://www.aurorasaurus.org/learn

https://spaceplace.nasa.gov/aurora/en/

https://science.nasa.gov/sun/auroras/

Session 9: Power Outages

Activity Overview:

Participants will use modelling clay and simple circuitry materials to learn how circuits work and explore how magnets can induce electricity. This will enable participants to understand how solar storms can cause power outages, which is represented in several of the mystery cards.

Duration: 45 min

Preparation:

- Make sure the power switch is off on the 6V battery holder, then place 4 AA batteries inside

Key Terms:

Electricity: A form of energy that comes from the flow of tiny particles called electrons.

Circuit: A loop-shaped path that electricity can move through.

Closed Circuit: An complete loop that electricity can flow through.

Open Circuit: An incomplete loop that electricity cannot flow through.

Current: The flow of electricity through something, usually a wire.

Induced Current: The current generated in a wire due to a changing magnetic field or differences in voltage.

Fuse: A device that shuts off the power to an electrical circuit when too much electricity flows through the circuit.

Volt: A unit of electric potential (Example: a six volt battery).

Solar Storm: A sudden explosion of particles, energy, magnetic fields, and other material blasted into the solar system by the Sun.

Geomagnetic Storm: When a solar storm causes a major disturbance in the Earth's magnetic field. This can cause issues such as radio blackouts, power outages, and aurora.

Geomagnetically Induced Currents: Electric currents that are created along the Earth's surface or through electric transmission lines as a result of solar storms causing a temporary change in the magnetic field.

Materials :

Per 2-3 Participants

- *6V AA battery holder* (x1)
- AA batteries (x4)
- 1 Red and 1 black *alligator clips*
- *Mini 6V light bulb* (x1)
- *Mini 1.5V light bulb* (x1)
- *Light bulb holder* (x1)
- *Modeling clay*
- Large paper clips (x2)
- *Steel wool* (grade 0)
- Cardstock sheet
- *Fuse example*

Useful Tip:

This activity involves burning steel wool, and some students might be concerned about fire. If students express fear about the sparks, remind students that there are safety precautions, and that they are protected. Feel free to share your institution's emergency safety plan.

Facilitation Tips:

It is helpful to use a visual presenter or document camera to project the activity so that students can follow along.

Do not provide batteries until the end!

Having red and black alligator clips will simplify the wiring when making the circuits. Typically red wires connect to positive sides of a circuit, and black wires connect to negative sides.

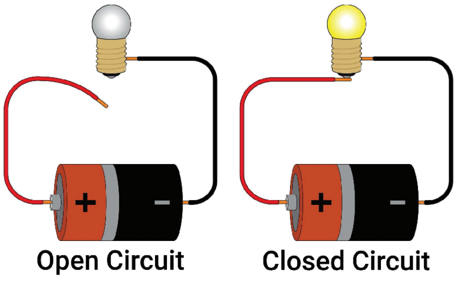
This activity does involve creating a spark. There is low risk of danger, but instructors should be sure to follow all of their institution's guidance and safety precautions.

Activity Procedure:

1. Watch an introductory video about how magnetism can induce electricity

 How Solar Storms Could Knock Out Our Power Grid by NOVA PBS Official. *https://tinyurl.com/PBSPowerGrid* (it will start at 3:38 minutes)

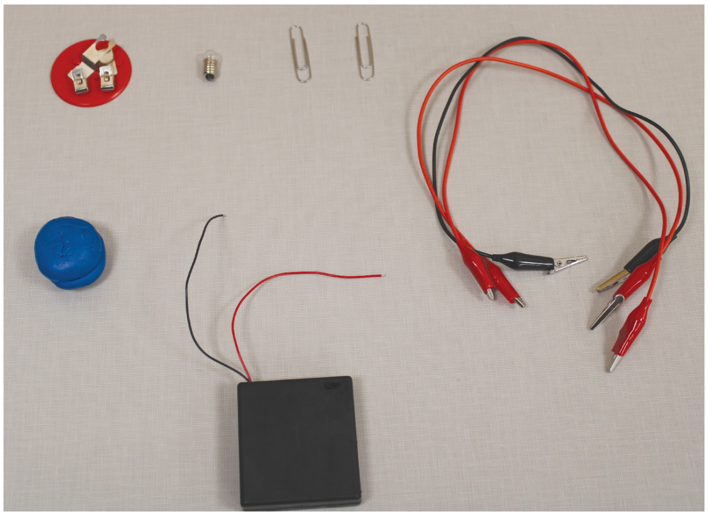
2. Lead a demonstration for the students where you create a simple circuit. Use a 1.5V battery and 2 alligator clips to light a 1.5V light bulb. Explain that the circuit is **closed** when the loop is complete and the lightbulb is on. Explain that the circuit is **open** when the loop is incomplete and the lightbulb is off.



3. Ask students what they think would happen if too much electricity flows through the lightbulb? Demonstrate how the lightbulb blows out if 6V batteries are connected to a 1.5V bulb

4. Distribute the following materials to the students and ask them to create a circuit. (Do NOT give them batteries). Explain that in a circuit, red typically represents the positive (+) side, and black typically represents the negative (-) side.
Make sure they connect a red wire from the positive side of the battery to one side of the light
Make sure they connect a black wire to the negative side of the battery to the other side of the light

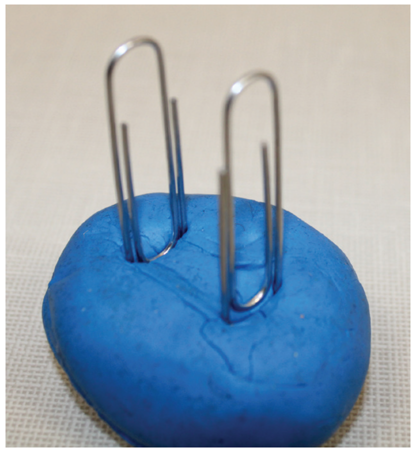
- 6V battery holder
- 2 alligator clips
- 1.5V light bulb
- Light Bulb holder



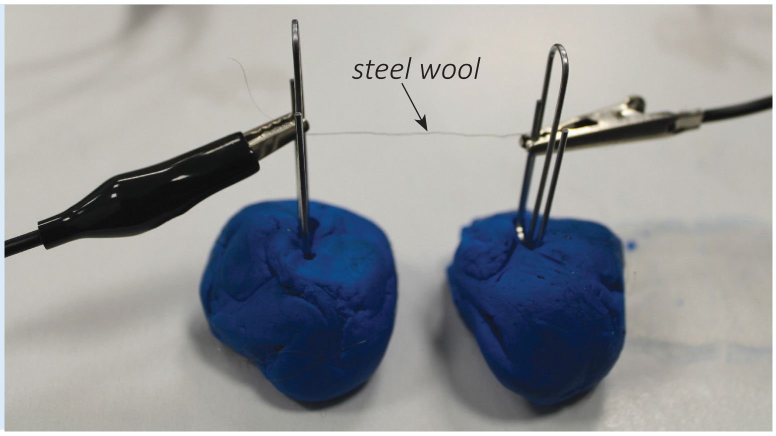
5. Ask students to think about what would happen if they put batteries in the holder. Challenge them to consider how they can prevent the bulb from blowing out?

6. Explain that we can build a **fuse** to shut off the power if too much electric current flows through

7. Distribute a chunk of modelling clay and 2 paper clips. Instruct students to create a fuse by rolling the clay into a ball and flattening it slightly (see below). Place the paper clips in the clay about 2 inches apart.

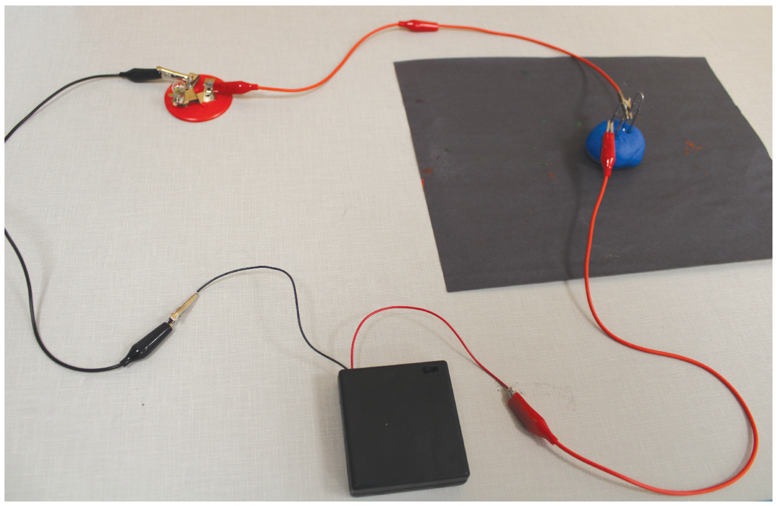


8. Place a single thread of steel wool between the paper clips by winding it around the paper clip creating a bridge between the two paper clips.

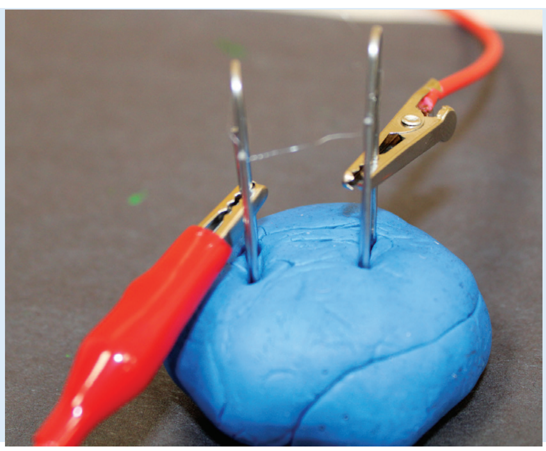


9. Show students an image of the completed circuit, and challenge them to replicate what they see. This step can be challenging. Essentially, the goal is to place the fuse in the middle of the positive (red) side of the circuit.

- First, they should unclip the red alligator clip from the light bulb and clip it onto one of the paper clips.
- Using a different red alligator clip, clip one side to the other paper clip, and the other to the light bulb (on the positive side that they removed the other alligator clip from)



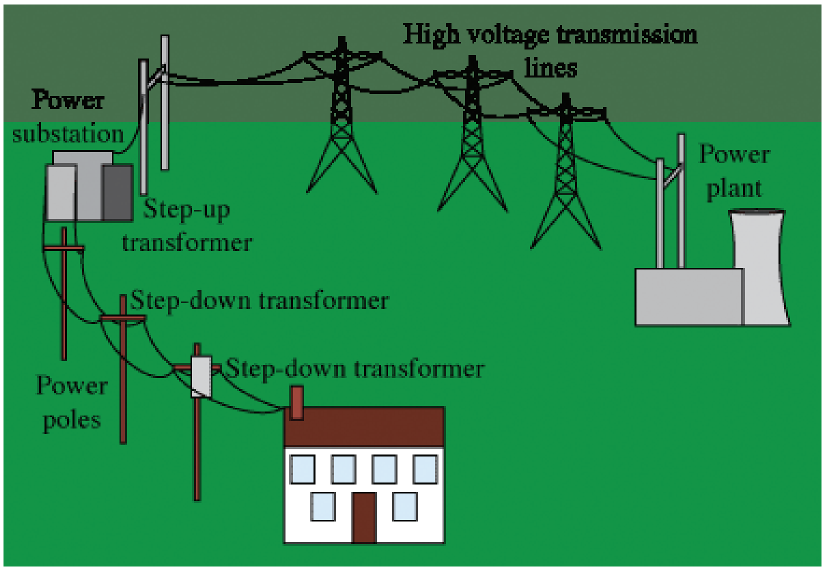
10. Place the batteries in the battery holder to complete the circuit. Turn the switch on. What do you notice about steel wool? Is your light bulb on or off?



11. Explain that the piece of steel wool acts like a fuse and represents how fuses work. Show an example of a fuse.
12. Discuss how the fuse examples are related to a power grid during a blackout.

Extension Ideas:

Participants can create a diagram or a map of the path of electricity from the power plant to their homes. See example:

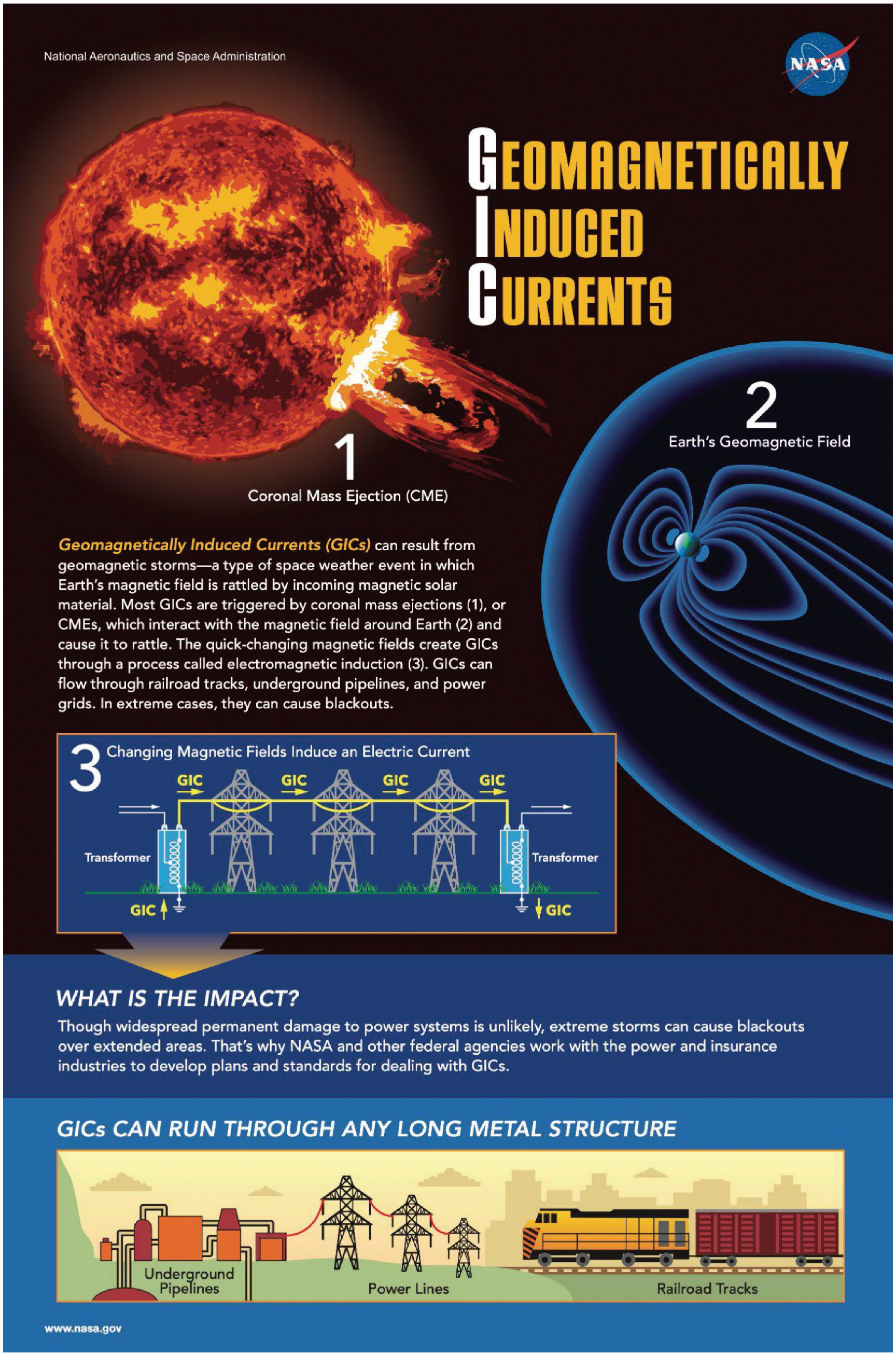


Background Science:

A disruption in a circuit can affect the flow of electricity. When the wire is disconnected, it opens the circuit and shuts off the lightbulb. When 6V batteries try to power a 1.5V light, there is an overflow of electricity which burns the fuse. Once the fuse is burned up, it creates an open circuit, preventing electricity from flowing to the bulb.

Solar storms can induce electricity that can overload our electrical grids. When this happens, it can cause a power outage that leaves a city without electricity. These phenomena are called **geomagnetically induced currents** (or GICs). A recent occurrence of a GIC happened over Europe in May 2024.

The Sun releases a constant stream of charged solar particles called the **solar wind.** Sometimes, huge clouds of solar material expelled from the Sun, called **coronal mass ejections,** can interact with the Earth's magnetic field, causing temporary changes. This temporary change can create electric currents on or under the Earth's surface called GICs. Metal structures near the Earth's surface (like underground pipelines, railroads, power lines) can act like giant wires for the GICs, causing electricity to flow long distances underground. These currents can knock out power systems and cause temporary blackouts.



Sources:

https://science.nasa.gov/sun/solar-storms-and-flares/

https://www.nasa.gov/science-research/heliophysics/living-with-a-star-nasa-and-partners-survey-space-weather-science/#:~:text=Geomagnetically%20Induced%20Currents%2C%20or%20GICs,a%20process%20called%20electromagnetic%20induction.

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2024SW004191

Session 10: Secret Messages

Activity Overview:

Learners will create glasses using red and green light filters. This will support their understanding of how light filters work and how scientists use filters to study the Sun and its light.

Duration: 20 min

Materials:

- Glasses template, see Additional Resources for an example
- Red filter, *Lee Filters Direct in 026 Bright Red Lighting Gel*
- Green filter, *Lee Filters Direct in 090 Dark Yellow Green Lighting Gel*
- Transparent tape
- Red crayons that match the red filter
- Green crayons that match the green filter
- Index cards or white paper

Preparation:

- Glasses:

  Cut out the glasses templates so that each student has two pairs of glasses

- Filters:

  - Cut out red and green squares of the filters so they are just big enough to cover the eyehole of the glasses
  - each student should have 2 red and 2 green filter squares

Key Terms:

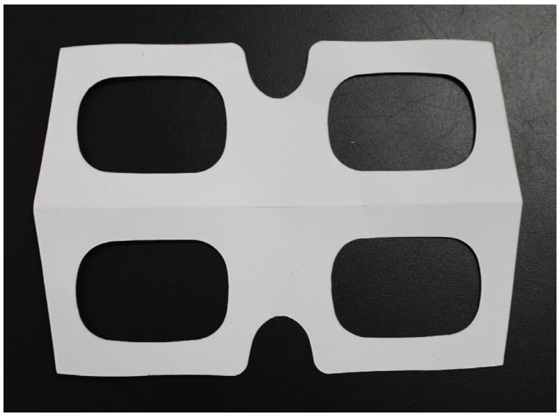
Reflection: When light bounces off a surface instead of passing through.

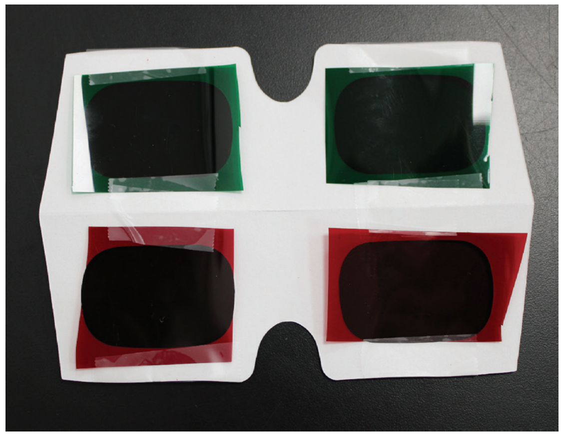
Absorption: When light enters a material and does not pass through.

Activity Procedure:

1. Ask students: “What color is light?” Explain that even though it’s called “white light,” it actually consists of all seven colors blended together (red, orange, yellow, green, blue, indigo, violet aka Roy G Biv.)
2. Ask students: “Why can we see colors?” Explain that when multicolored “white” light shines on an object, it absorbs some colors and reflects others. For example, if you look at an apple and it appears red, it’s because the apple is absorbing all colors except red. Instead of absorbing red, the red light bounces off the apple and is reflected back to you and you see the apple as red.
3. Ask students: “What do you think our perception of color would be if the sun’s light wasn’t this mix of colors? What if it was only one color?” Take note of their predictions.
4. Time to find out! Pass out the glasses, filters, and tape.

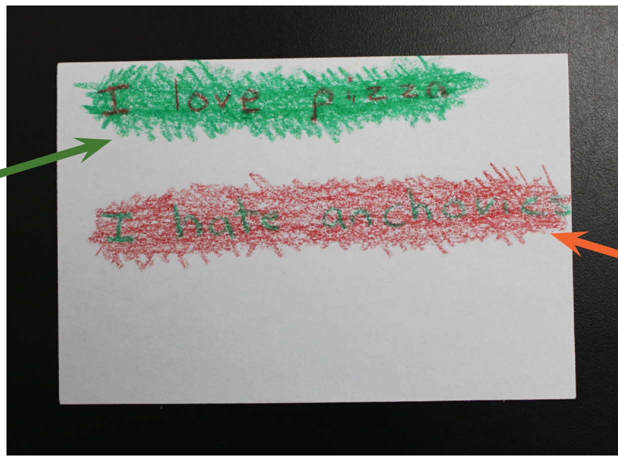
5. Have students take one pair of glasses and both red filters. Tape the red filters over the eyeholes of the glasses. Make sure the vision isn't obstructed by the tape.
6. Repeat step 5 with the other glasses and the green filters.





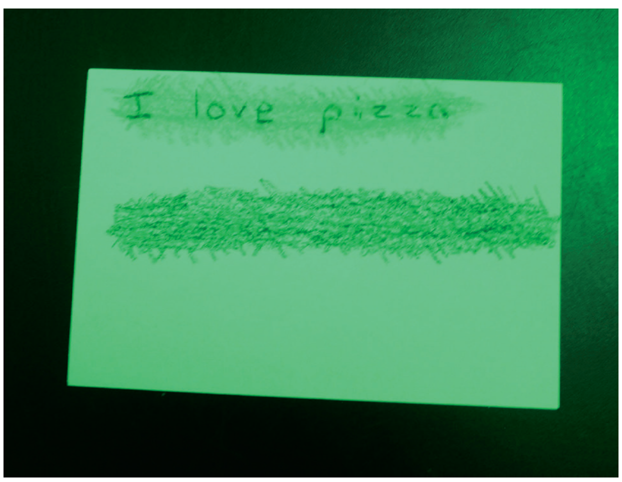
7. Give students index cards and a green and red crayon. Have them write messages in one color, then scribble over whatever they wrote in the other color.
8. Have them do the same thing but in reverse (aka swap which color is the message and which color is the scribble.)

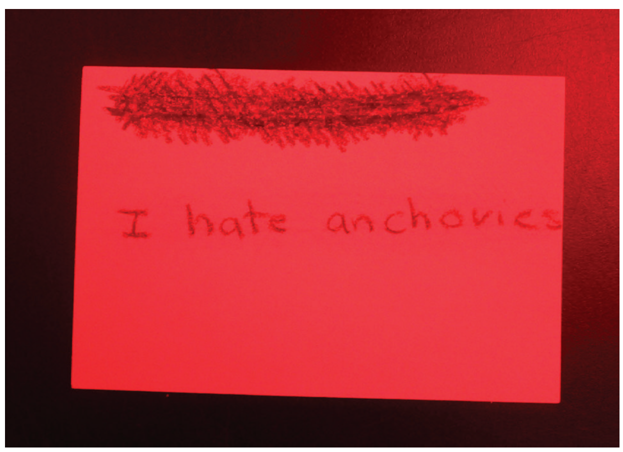
Red text and green scribble



Green text and red scribble

9. Encourage students to look at their images through each filter.
   What filter makes the red message readable?
   What filter obscures the red message? What about the green filter?





Extension Ideas:

Try the Optics: How Do We See Color activity from the *Year 1 curriculum*.

Background Science:

Lightwaves exist on a spectrum, and the part we can see is called "visible light." Visible light consists of red, orange, yellow, green, blue, indigo, and violet light. When blended together, this is called "white light." When we look at a colorful item, we see the color that is reflected back to us. For example, if you look at a red ball, white light is shining on that ball. In this example, all of the colors of white light except red are being absorbed by the ball. Instead of being absorbed, red is reflecting off the ball and entering your eye, allowing you to perceive the ball as red.

When participants look through the green filter, all colors are filtered out except green. Because the green crayon is the same color and shade as the filter, it is hard to see the green writing on the white index card (since the green filter is only letting green light through). The same thing happens when using the red filter and a red crayon: the red filter only allows red light to pass through, making it difficult to see the red crayon. Since red and green are opposite colors, when you use a red filter and a green crayon (and vice versa) the writing will appear almost black.

Similar to how we use red and green filters to change what we perceive on index cards, NASA uses filters to perceive the Sun in different ways. While the filters in this activity are limited to the visible light spectrum, NASA uses many types of filters, including infrared and ultraviolet. These filters help ensure only specific, desired wavelengths reach the detector of the telescope, allowing NASA to get the specific wavelength information it needs.

NASA also uses filters to create full color images. A telescope or rover will take the same photo three times, using red, blue, and green filters each time respectively. NASA will then combine these single filter images afterwards to create the full color photos with which we're familiar.

Additional Resources:

https://science.nasa.gov/resource/filters-for-color-imaging-and-for-science/

https://science.nasa.gov/solar-system/multimedia/raw-images-faq/

Session 11: Solar Ovens

Activity Overview:

Students will build a device that creates heat using solar power. Using their solar ovens, they will experiment with melting different items.

Preparation:

- Collect closable cardboard boxes. They should be roughly 12x12x2”. Different sized boxes may take different amounts of time to heat up. Examples: pizza boxes, small shoeboxes, cereal boxes.
- Choose if you want the students to melt edible or non edible items. Edible items can include gummy candies or s’mores supplies (graham crackers, marshmallows, chocolate squares). Non-edible items can include crayons.
- Find a safe space in direct sunlight to leave the solar ovens unattended. Since cook times can be long, it may not be ideal to have students outside the entire time.
- Create some pre-made components to have on hand for students that struggle with fine motor skills.
- Choose a day with warm temperatures and direct sunlight. It may be helpful to do a test run to determine how long it will take in your geographic area/time of year.

Key Terms:

Solar: Related to the Sun.

Useful Tip:

- Bright light can be difficult for students with light sensitivity. Consider having sunglasses available for when you go outside.
- Some students may struggle with cutting and other fine motor skills. If a student is struggling or frustrated, either assist them or provide them with pre-made components.
- Some students may have sensory based issues with the materials used in this activity. Working with a partner can allow students to share the load deciding which materials they want to handle.
- Print the visual guide as an option for students to follow along at their own pace. [Solar Ovens *Visual Guide pdf*]

Duration:

Building Time: 30 min

Cooking Time: Varies depending on temperature and strength of sunlight. On a sunny and hot day, it can be as quick as 20 minutes. On a cooler and less sunny day, it can take an hour or more.

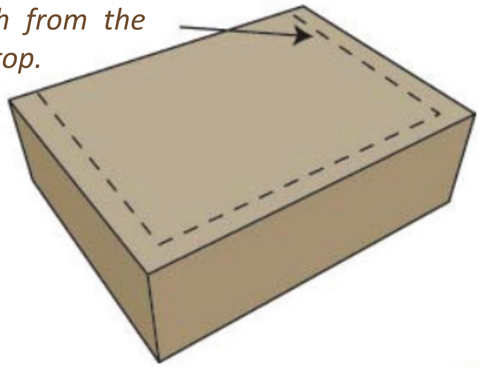
Materials:

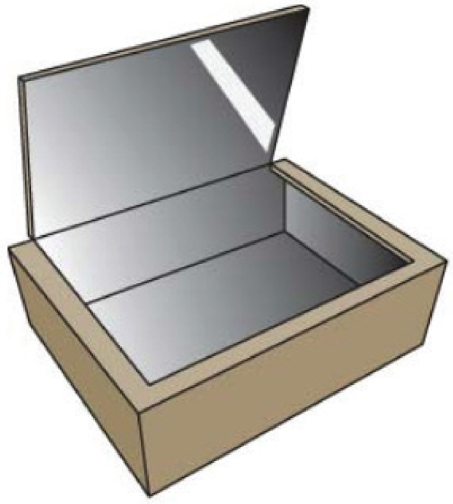
- Closable cardboard box (see preparation section)
- Aluminum foil
- Clear plastic wrap
- Gluesticks
- Masking tape
- Ruler
- Stick or dowel to prop the lid open
- Meltable items (see preparation section)
- *Optional: Temperature gun or thermometer*

Activity Procedure:

1. Using a ruler as a guide, cut a three-sided flap out of the top of the box leaving at least a 1” border around the three sides.

Cut here, 1 inch from the edge of the boc top.

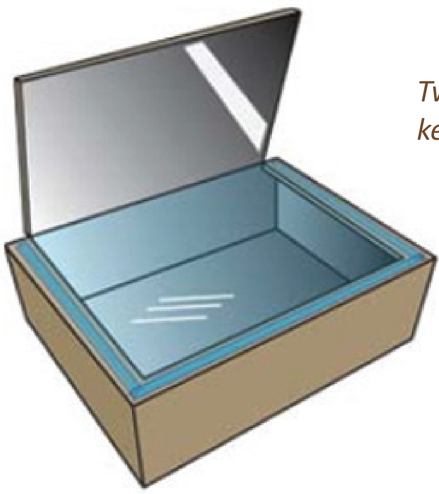




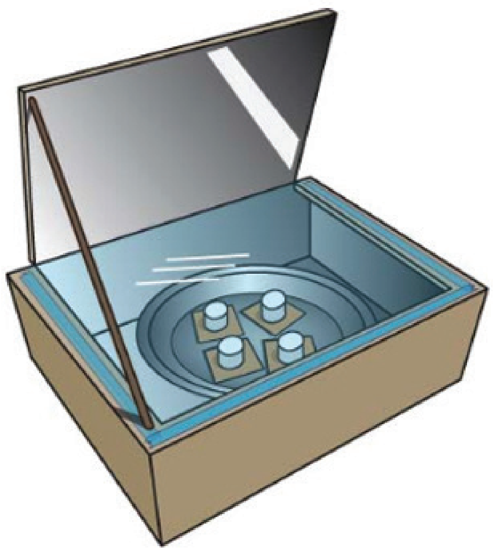
2. Use the glue stick to spread a coat of glue on the bottom (inside) of the flap. Cover the glue with a piece of aluminium foil, making sure the foil is as smooth as possible. The foil should completely cover the inside.

Make sure the foil inside the flap is very smooth, to make it like a mirror.

3. Tape plastic wrap across to cover the box. Use masking tape so you can peel away one side of the plastic wrap to place food or objects inside. The Masking tape will allow you to reseal the solar oven when you’re ready to use it. Two layers of plastic wrap are recommended for better insulation across the opening of the box.



Two layers of plastic wrap over the opening will help keep heat in, while still letting all the light shine through.



4. Use the stick to prop up the lid. You may need to use tape to keep it in place.

5. Test your solar oven! Take it outside and place it in a sunny spot.
6. Open the box to place your object to be melted inside.

   Optional: Use a temperature gun or thermometer to measure and record the starting temperature of the solar oven.
7. Once items have been melted, you can eat them (if edible). If melting crayons, give them time to cool before using them.

   Optional: Use a temperature gun or thermometer to measure and record the ending temperature of the solar oven.

Extension Ideas:

- This project helps visualize the Sun's power and demonstrates how the Sun's power can be directed and utilized. For another project that builds on that concept, see *Activity 12: Solar Powered Cars*.
- Let kids get creative with their designs and compare how different builds affect the function of the solar ovens.

Background Science:

The Sun generates A LOT of energy. On average, every square meter of Earth receives 342 watts of solar power in a year, which is a cumulative 44 quadrillion watts of power overall. To generate that amount of energy, you would need 44 million power plants each generating 1 billion watts per year.

Some of the energy Earth receives is heat, specifically near-infrared light. The Sun contains a lot of hydrogen and is very, very large. This means it also has a lot of gravity, which creates a lot of pressure inside the Sun. Due to this pressure, nuclear fusion occurs as the Sun's hydrogen atoms collide and fuse into helium. This process (which repeats) releases a lot of energy, which turns into heat (at 15 million Kelvin or 27 million degrees Fahrenheit!) By the time the energy reaches the Sun's photosphere, the temperature is closer to 6000 Kelvin. Some of this heat is discharged and makes its way to Earth, warming our planet (and our s'mores).

However, much of the Sun's energy never makes it to the Earth's surface, since our planet protects us by reflecting and emitting most of this energy back into space.

Sources:

Solar Ovens *Printed Visual Guide*

https://www.nasa.gov/wp-content/uploads/2015/03/135642main_balance_trifold21.pdf

https://spaceplace.nasa.gov/sun-heat/en/

https://earthobservatory.nasa.gov/features/RenewableEnergy/renewable_energy4.php#:~:text=Sunlight%20passes%20through%20the%20transparent,heat%20to%20achieve%20cooking%20temperatures.

Session 12: Solar Powered Cars

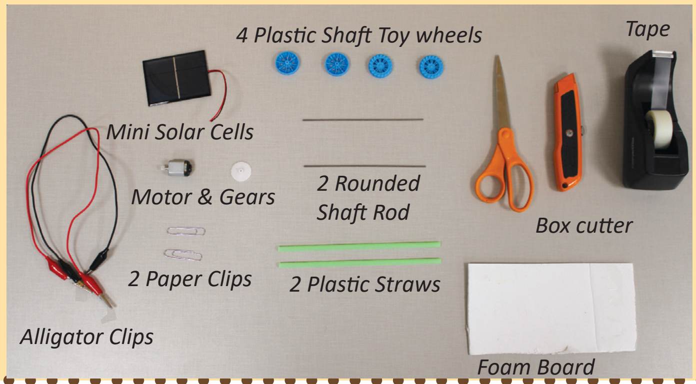
Activity Overview:

Students will use simple circuitry materials and solar panels to build solar-powered model cars. Students will understand that the Sun is a source of energy that can be converted into electrical energy that can power a car.

Duration: 1-2 hrs

Materials:

- 4x6" corrugated cardboard or foam board
- Clamp lights
- Flood light (or other strong light)
- Solar Panels: *AMX3d Micro Mini Solar Cells – 1.5V 400mA 600mW Compact 80 x 60mm Solar Panels*
- *DC 1.5-3V 15000RPM Mini Electric 130 Motor Kit*
- Wheels *- 30mm x 8mm Plastic Roll 2mm Dia Shaft Toys Wheel*
- Alligator clips
- Plastic straw cut into 2 3-4 inch
- Axle *- Stainless Steel 150mm x 2mm Round Shaft Rod*
- Gear on the motor: *Modle: 092A; Number of teeth:9 ; Modulus: 0.5 Modulus; Outer diameter: 5.5mm; Hole diameter: 2mm; Thickness: 5mm*
- Gear on the axle*: Plastic Gears Model 50102A, 50 Teeth, 0.5 Modulus, 26mm Outer diameter, 5.7mm Thickness, 2mm Hole Diameter.*
- Masking tape or clear tape
- Paper clip
- Box cutter
- *(Optional)* Suggested Solar Powered Car Kits:
  - *- Solar Made*
  - *- Solar DIY Micro Car Kit*
  - *- Pitsco Kit*



Useful Tip:

If it's bright outside, have sunglasses available for students with light sensitivity.

Preparation:

- This activity works best on a sunny day, so try and schedule it for a day with Sun!
- Pre-cut cardboard into 4 in. x 6 in. pieces.

Key Terms:

Solar Power: Power generated directly from sunlight.

Solar Panel: Panels made out of cells that turn solar power into electricity.

Circuit: A path for electricity to travel through.

Chassis: The car's frame, or body.

Axle: Straight, rigid rods that support the wheels.

Bearings: Mechanical parts that connect the axle to the chassis while still allowing the wheels to spin

Motor: Converts electrical energy (in this case from the solar panel) into a spinning motion that can be used to turn wheels.

Transmission: Transmits rotating motion from the motor's shaft to an axle

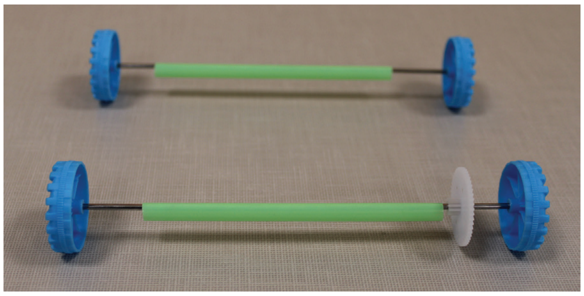
Gears: Mechanical parts with cut teeth designed to fit with teeth on another part, as a means to transmit or receive force and motion.

Activity Procedure:

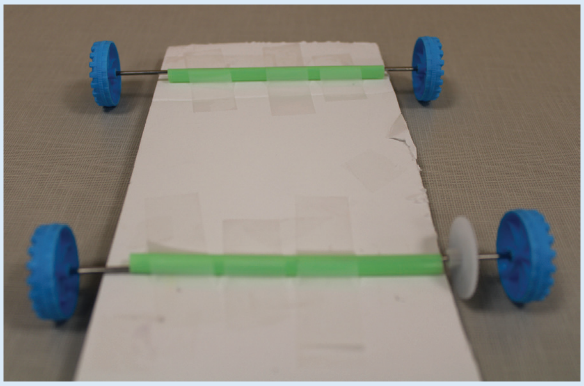
1. Recap what a circuit is, and demonstrate how solar panels can power a light bulb like a battery.

2. Instruct students to slide an axle (metal rod) into a bearing (straw). Press a wheel (plastic discs with rubber tire treads) onto the ends of the axle

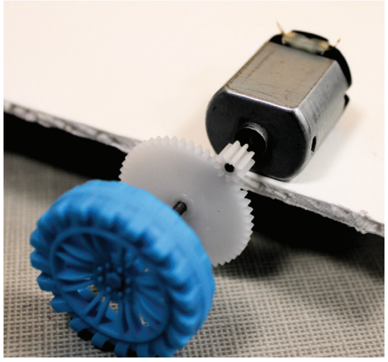
3. On the other axle, follow the same steps, but make sure to slide a plastic gear onto the axle before attaching the second wheel.

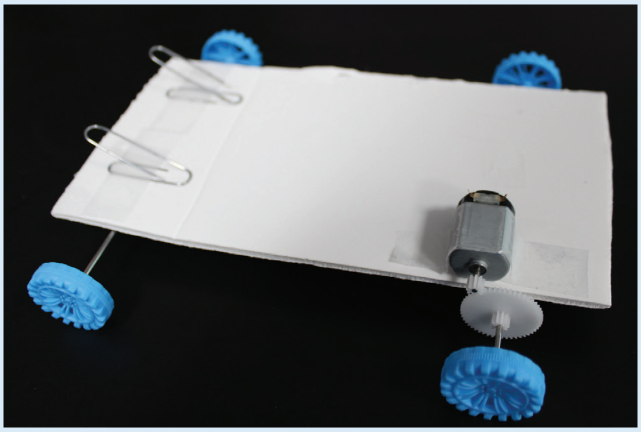


4. Construct the chassis. Lay down the cardboard/ foam core on the table and place the axles/ wheels on top so that it resembles the wheels of a car. Make sure the wheels and gear are hanging over the edge of the chassis and able to spin. Tape the straws onto the cardboard.

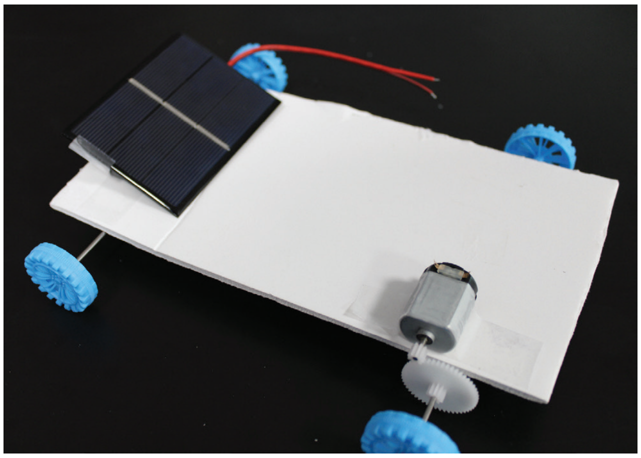


5. Tape the motor to the chassis and align the transmission with the teeth on the motor. This step is challenging! If using gears, the teeth need to mesh firmly. If they are too loose or not touching, the motor will spin without turning the axle. If they are too tight, there may be too much friction, which can cause a jam. You can test and adjust once it is connected to the solar panel.

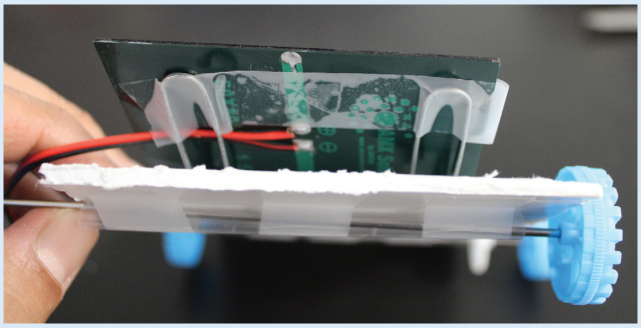




6. Attach supports for your solar panel to the chassis. Use a bent paper clip (like a hook) and tape it to the back of the chassis.

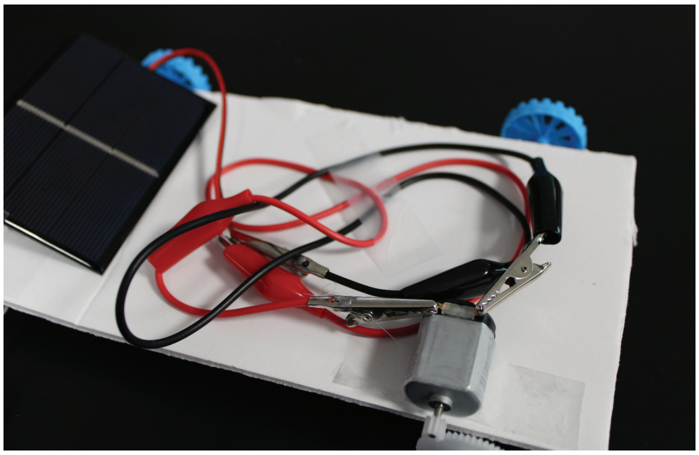


7. Place the solar panel on the paper clips with the panels facing upward.

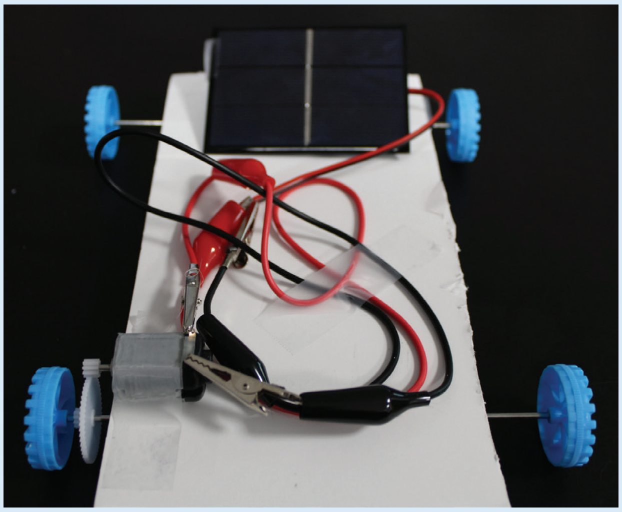


8. Use tape to secure the solar panel to the paper clips.

9. Connect a red alligator clip to the red wire on the solar panel. Make sure it touches the metal part that extends off the red wire. Do the same thing with the black alligator clip and black solar panel wire. Connect the other end of the red alligator clip to one metal prong on the motor. Connect the other end of the black alligator clip to the other metal prong on the motor.



10. Test your car! Take your car outside in direct sunlight, but don't put it down yet. Hold it in your hands and aim the panel towards the Sun. If the motor and axle both spin, it works!



Troubleshooting:

1. If the motor doesn't spin at all:
   - Check if there is enough light. The motor may not spin in the shade or under clouds. If needed, adjust the paper clips to angle the solar panel towards the Sun.
   - If it still doesn't spin, double check the circuit. Make sure the alligator clips are firmly attached to the metal parts of the solar panel wire. Make sure that none of the wire connections are loose or broken.
   - If it still doesn't spin, check if there is a jam in the axle or transmission. Does the axle spin if you twist the wheels by hand?
2. If the motor spins but the axles do not:
   - Make sure the gears are touching or connected firmly together
   - Realign the gears by moving them either closer or slightly apart from each other

Extension Ideas:

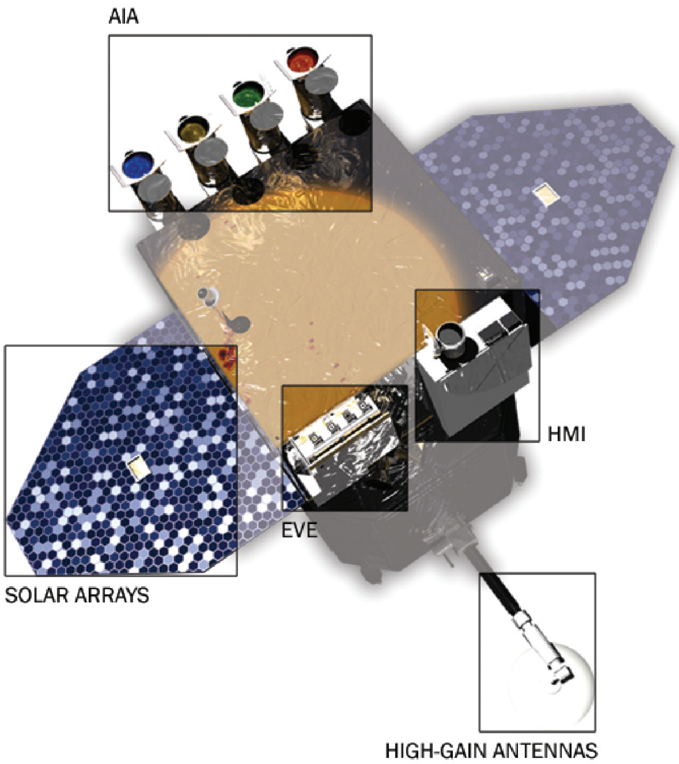
- Explore different materials for the chassis (it just needs to be sturdy)
- Explore using different materials for the wheels and axles (ex: bottle caps, skewers)
- Change the gear size and gear ratio and experiment with the car's movement
- Use the solar panels to make different circuit creations

Background Science:

Solar panels convert sunlight into electrical energy. This electrical energy runs through the wires and alligator clips to the motor, turning the electrical energy into mechanical energy that powers the motor. The motor turns the gears, which causes the wheel and axle to turn, which then causes the car to move. If the Sun can't reach the solar panel, the panels won't collect enough energy to power the car.

Unlike fossil fuels, which cause pollution and emit greenhouse gases, solar power is a clean and renewable energy source. However, there are challenges to using solar power. For example, it is not available at night or on a cloudy day.

Many spacecraft, rovers, and space telescopes rely on solar panels called "solar arrays" to provide their energy. The solar arrays charge batteries on the spacecraft to provide power during nighttime. One example is a spacecraft called the "Solar Dynamic Observatory" or SDO. The SDO orbits Earth and studies the solar activity of our Sun by measuring its magnetic field and creating images of its outer layer. Its solar arrays provide the energy needed to complete these tasks, enabling scientists to analyze the Sun's activities. These images can be viewed at *www.helioviewer.org.*



EVE (Extreme Ultraviolet Variability)
HMI (Helioseismic and Magnetic Imager)
AIA (Atmospheric Imaging Assembly)

SDO powered by the Sun's energy using solar arrays.

Additional Resources:

Check out the Solar Ovens activity for another activity harnessing the Sun's energy.

Sources:

https://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p043/energy-power/how-to-build-solar-powered-car

https://sdo.gsfc.nasa.gov/mission/spacecraft.php

https://kids.kiddle.co/Machine

Session 13: Moon Balls

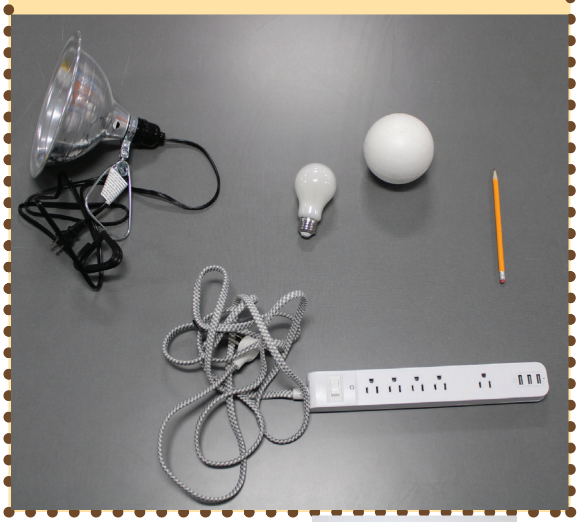
Activity Overview:

Students will engage in a kinesthetic activity that models the positions of the Earth, Sun, and Moon. This activity will help students understand the phases of the Moon during its (almost) 30 day cycle, and relate this knowledge to what happens during an eclipse.

Duration: 30-40 min

Materials:

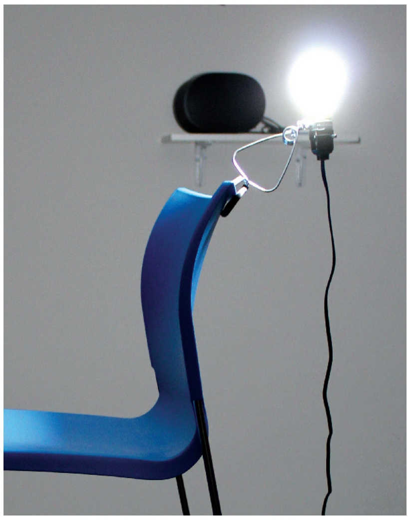
- Styrofoam balls (4-5” diameter)
- Pencil
- Stationary light source with a 100 watt lightbulb. Ex:
  - Clamp light
  - Lamp without a shade
- Extension cord
- Table or chair



Preparation:

- Use a dark room for this activity and move desks and other objects out of the way so students can move around freely.
- If using a clamp light, remove the reflector (shiny dome piece). If using a traditional lamp, remove the shade.

- Set up the light source in the middle of the room. If using a clamp light, clamp it to a table, desk, or chair back. Face the light upward. If using a lamp, place it on the table.



- Pre-poke holes in the styrofoam balls.

Key Terms:

Moon Phases: The different shapes of the Moon that we see at different times of the month.

New Moon: When the Moon is between the Sun and Earth so that the lighted side faces the Sun and the dark side faces Earth.

Waxing Crescent: Lit from the right side and can usually be seen within 24 hours after a New Moon. Waxing means that it is slowly getting more light (and appearing bigger).

First Quarter: About a week after the New Moon, half of the Moon is lit from the right side. Since it is half of one side of the Moon, it is referred to as a quarter.

Waxing Gibbous: When more than one quarter of the Moon is visible, it is a gibbous. Since it's lit from the right and growing, it is waxing. Gibbous is latin for "humpbacked"

Full Moon: When the entire lighted side of the Moon is visible from Earth. The Moon is on one side of the Earth, and the Sun is on the other side.

Waning Gibbous: When more than one quarter of the Moon is visible from the left side. Waning indicates it is getting less light (appearing smaller). This begins right after a Full Moon.

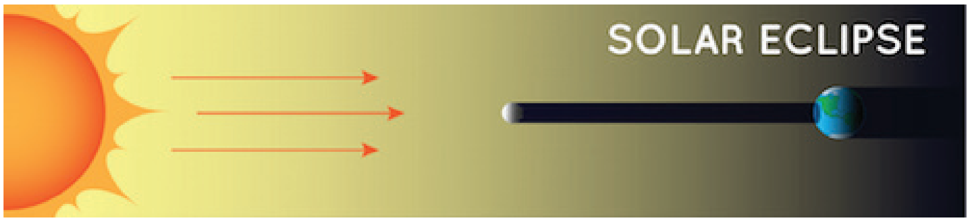
Third Quarter: About a week after the Full Moon, you can see half of the lighted side (which is a quarter of the Moon). This is lit from the left side.

Waning Crescent: Lit from the left side and usually seen within 24 hours before a New Moon.

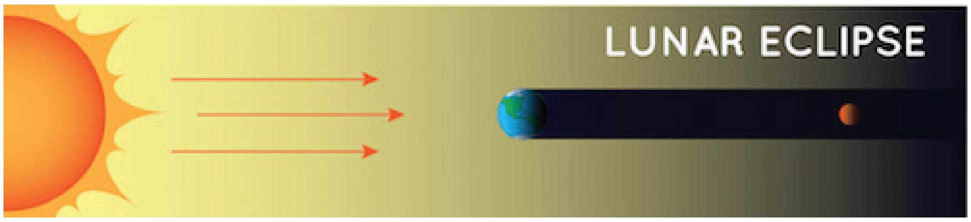
Orbit: A regular, repeating path that one object in space takes around another. An object in orbit is called a satellite.

Eclipse: When a planet or moon gets in the way of the Sun's light. On Earth, we can experience two types of eclipses: solar and lunar.

Solar Eclipse: When the moon blocks the Sun's light and creates a shadow on Earth.



Lunar Eclipse: When the Earth blocks the Sun's light from reaching the Moon.



Facilitation Tips:

- Prior to the activity, ask participants if they know the different phases of the Moon and what they look like. Use this *NASA resource* to show participants pictures of the different phases.
- Remind students to be careful when using the pointed end of the pencil.
- Remind students not to look at the light source directly.
- Practice quarter, half, three quarter, and full body turns with the students before doing the activity with the light source.
- Practice turning while holding the moon balls. It might be helpful to use a round clock as a reference for turning instead of using degrees.
- If the room is small and can't accommodate all of the students at one time, break them into smaller groups and take turns.

Guiding Questions:

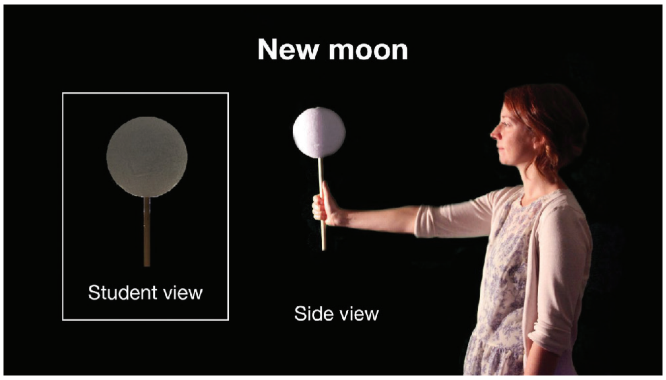
- What is the light source that allows us to see the Moon?
- How do the Earth, Moon, and Sun orbit around each other?
- What is the order of Earth, Moon, Sun during a solar eclipse?
- What is the order of Earth, Moon, Sun during a lunar eclipse?
- Choose one phase of the Moon and describe what is happening

Activity Procedure: *Part 1: Setting the Stage*

1. Tell the participants that we are going to simulate the phases of the Moon using a light source, styrofoam ball, and our body movement.
2. Explain that the light source will represent the Sun. Have students stand in a circle around the light source.
3. To make sure everyone is properly spaced and has enough room, have each student extend their left arm. If they are touching the person to their left, they need to step back.
4. Distribute a styrofoam ball to each participant. Tell participants to insert a pencil in the styrofoam ball. This will represent the Moon on its axis.
5. Tell participants their heads will represent Earth, and their nose will represent a mountain called "Mount Nose." Imagine you are standing on Mount Nose.

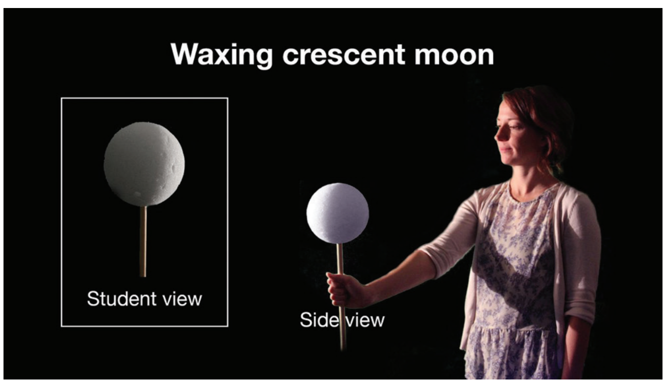
Part 2: Acting out the Moon Phases

1. **New Moon:** Ask participants to face the light source and hold the styrofoam ball directly in front of them while extending their arm. Slightly raise the styrofoam ball to see the light bulb below the styrofoam ball. Students will not be able to see the light on the moon, as the light will be shining on the side of the moon ball that they are not facing. Explain that when the Moon is not visible from the Earth, it is called the **New Moon**.

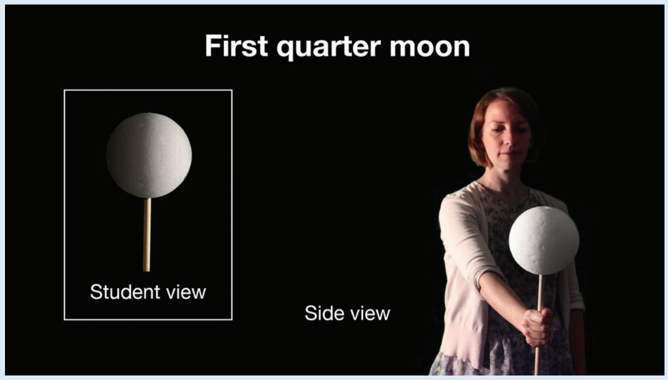


2. **Solar Eclipse:** To simulate a solar eclipse, have the participants block the light source where the shadow of the styrofoam ball falls on their face. They can easily view this from the other participant using the styrofoam ball next to them.

3. **Waxing Crescent Moon:** Keep the styrofoam ball extended in front of their body, and have students turn their body 45 degrees counterclockwise. They should begin to see the right side of the sphere illuminated and creating a crescent shape (like a curved banana). As they move counterclockwise, more of the moon ball will become illuminated. Explain that this phase is called the **Waxing Crescent Moon.**

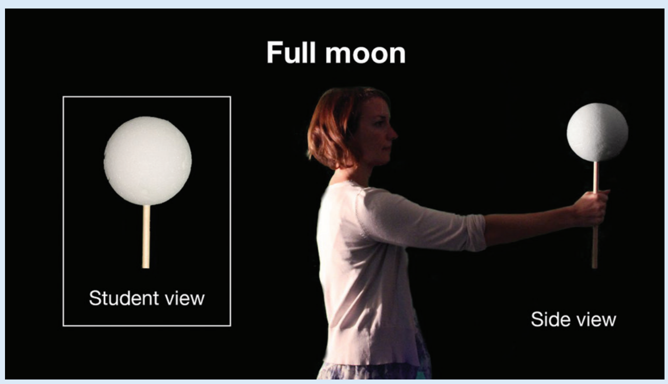


4. **First Quarter Moon:** Tell participants to move an additional 45 degrees counterclockwise (90 degrees from the original position) while keeping the moon in front of their body. The right half of the sphere should be illuminated. This phase is called the **First Quarter Moon**.



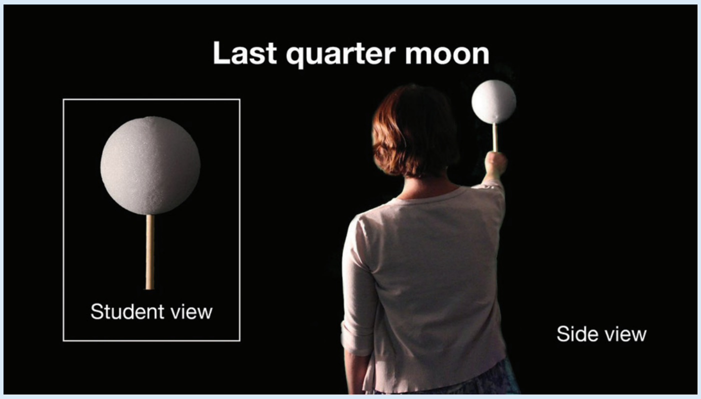
5. **Waxing Gibbous Moon:** Have the participants turn an additional 45 degrees counterclockwise (135 degrees from the original position) while holding the moon in front of them. The moon should be largely illuminated, but not fully. This is called the **Waxing Gibbous Moon.**

6. **Full Moon:**Have the participants turn their body an additional 45 degrees (180 degrees counterclockwise from the original position). Their backs should be facing the light source. Hold the moon in front of Mount Nose, and lift it up high enough so that your head is no longer blocking the light. The moon should be fully illuminated. This is the **Full Moon**.



7. **Lunar Eclipse:** To simulate a lunar eclipse, hold the moon in front of Mount Nose and have the shadow of your head fall on the moon as you move the moon counterclockwise.

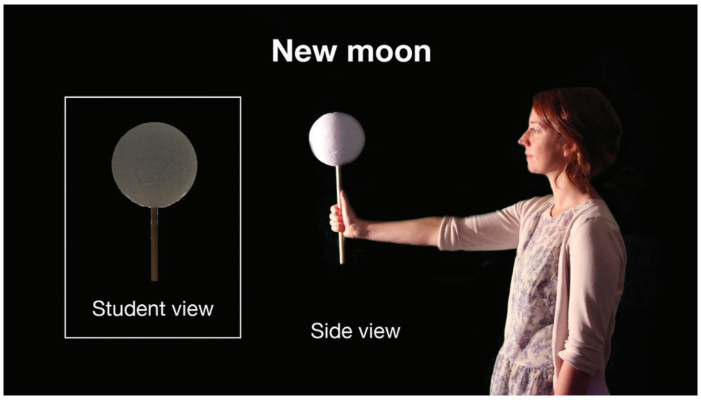
8. **Waning Gibbous Moon:** 8. Have the participants continue to turn 45 degrees counterclockwise (225 degrees from original position) from the full moon position. They should notice the moon becoming less illuminated. This is called the **Waning Gibbous Moon**.



9. **Third or Last Quarter Moon:** Have the participants turn an additional 45 degrees counterclockwise (270 degrees from original position). The left half of the moon should be illuminated (compared to the right side in the First Quarter). This is called the **Third** or **Last Quarter Moon.**

10. **Waning Crescent Moon:** Have participants turn an additional 45 degrees counterclockwise (315 degrees from original position) while holding the moon in front of them. They should begin to see the left side of the moon illuminated and creating a crescent shape (like a curved banana). This phase is called the **Waning Crescent Moon**.

11. Continue to turn counterclockwise until you return to your original position (360 degrees). The illuminated part of the moon should continue to get smaller, returning to the **New Moon**. The cycle is now complete!



Background Science:

The different phases of the Moon depend on where the Moon is in orbit around the Earth. As seen in this demonstration, the Sun illuminates half of the Moon, and we only see a section of the illumination from our perspective on Earth. When the Moon is in orbit between the Sun and Earth, we experience the New Moon. As it orbits counterclockwise, we see more parts of the Moon that are illuminated until it reaches the Full Moon. The Full Moon is when the Earth is between the Sun and the Moon. As the Moon continues to orbit the Earth, we see less and less illumination until it reaches the New Moon again. This cycle repeats every 28 days.

Because the Moon's orbit is tilted, the placement of its shadow changes. This is why there isn't a solar eclipse every month. Sometimes the Moon's shadow is too high above Earth, and other times it's too low. Occasionally, the shadow is just right, producing an eclipse.

The Moon does not produce its own light. The Sun is the only source of light in the solar system. Without the Sun, our Moon would be completely dark. What you may have heard of as "moonlight" is actually just the sunlight reflecting off the Moon's surface.

The Sun's light comes from one direction, and it always illuminates one half of the Moon (the side facing the Sun). The other side of the Moon is dark.

Sources:

https://www.jpl.nasa.gov/edu/teach/activity/moon-phases/

https://www.jpl.nasa.gov/edu/teach/activity/model-a-solar-eclipse/

https://spaceplace.nasa.gov/moon-phases/

https://spaceplace.nasa.gov/orbits/en/

https://science.nasa.gov/resource/why-dont-we-have-a-solar-eclipse-every-month/

https://spaceplace.nasa.gov/eclipses/en/

Session 14: Eclipses Through History

Activity Overview:

Students will explore how people in the past experienced and understood eclipses. Based on this history, students will create their own fictional or nonfictional eclipse stories. By gaining context for the magnitude of an eclipse and the unifying experience of witnessing one, students will engage more deeply in the topic and create their own meaning.

Duration: 20 min

Materials:

- *Slides* (239-243)
- *Optional: Print out templates of a scroll or other suitably historic theme such as a stone template, old-looking book, etc.*

  Example of a scroll template: https://timvandevall.com/templates/blank-scroll-templates/
- Writing Utensils

Useful Tip:

Some students may enjoy the creative and inventive aspects of this activity, while others might find venturing into hypotheticals and mystical elements unpleasant or off-putting. Explain that their eclipse stories can stick to known science if they prefer (instead of creating fictional omens/mythologies).

Preparation:

- Collect eclipse stories, histories, and traditions you wish to share.
- Print out scroll/historic-looking templates.

Key Terms:

Solar Eclipse: When the Sun and Moon line up in a way that allows the Moon to block the Sun's light, as seen from a point on Earth" to the end of the definition.

Prophecy: A prediction of what might happen in the future.

Omen: An event that is seen as a sign of something that will occur in the future.

Tradition: The handing down of beliefs, customs, and information from one generation to the next.

Mythology: A rich collection of traditional stories from different cultures.

Activity Procedure:

1. Begin by watching *"How Eclipses Changed History" by NPR's Skunk Bear.* This video covers the history of human observance of the eclipse
2. Share some selected stories (places to find stories listed in "Additional Resources" section below)
3. Tell students that now is their opportunity to create their own eclipse story. This can include predictions, omens, traditions, mythology, or anything in between. They are encouraged to be creative!
   - What kind of events does the eclipse foretell?
   - What ways will you observe the eclipse?
   - Is it a moment to celebrate or be wary?
4. If students are comfortable, they can share their stories with the whole group.

Extension Ideas:

• Students can do their own research and present historic eclipse stories to their classmates. One way to organize this is to assign them specific regions to study.

• Stories can be shared in various ways. Students can write, act out scenarios, draw pictures, create collages, etc.

• If students are interested, explain that archaeoastronomy is a study that combines science, history, archaeology, anthropology, and more. Archaeoastronomists study how people in the past understood celestial phenomena, and use that information to help guide astronomers today.

Background Science:

The solar eclipse is a celestial event that has been occurring long before recorded history, and even before humans ever walked the planet. Solar eclipses have been seen all over the world. Thus, they are a phenomena that people all over the world, all throughout history, have witnessed. The first known record of the eclipse may be a cave drawing found in County Meath, Ireland at the Loughcrew Megalithic Monument. The drawing dates to 3340 B.C.E and depicts a series of spiral-shaped and circular petroglyphs.

Just over 2,000 years later another recording of an eclipse appears to be made, 4500 miles away in Anyang, China. Images of the eclipse were carved into oxen and tortoise bones that can be dated to 1200 B.C.E. Those bones actually helped NASA properly calculate the Earth's orbit in the 1980s and 1990s:

> Determining exactly when the eclipse was seen and where the Moon's shadow fell on Earth helped them calculate the rate of Earth's spin. The eclipses they used for this research were in 1226 B.C.E., 1198 B.C.E., 1172 B.C.E., 1163 B.C.E., and 1161 B.C.E. If Earth were rotating at the same speed it is now, these eclipses would have occurred thousands of miles from Anyang. Since we know they occurred in Anyang, the scientists concluded that Earth's rotation had slowed by 47-thousandths of a second per day in the past 3,200 years (https://science.nasa.gov/eclipses/history/)

Besides the scientific study of the eclipse, human cultures all over the world have found great significance and meaning in moments of solar eclipse. For many, seeing the Sun disappear from the sky in the middle of the day could be a terrifying event that indicates bad omens.

Additional Resources:

Here are some sources for learning about how humans throughout time have talked about the eclipse:

https://eclipse2017.nasa.gov/eclipse-history
https://www.history.com/news/solar-lunar-eclipses
https://www.newsweek.com/what-solar-eclipses-meant-ancient-cultures-651206
https://www.vox.com/culture/2017/8/18/16078886/total-solar-eclipse-folklore
https://www.nytimes.com/2017/08/18/science/solar-eclipse-myths.html
https://www.livescience.com/60139-why-eclipses-frightened-ancient-civilizations.html
https://theconversation.com/how-ancient-cultures-explained-eclipses-79887
https://www.smithsonianmag.com/science-nature/how-ancient-civilizations-reacted-to-eclipses-180983894/
https://www.scientificamerican.com/article/how-ancient-humans-studied-and-predicted-solar-eclipses/
https://www.exploratorium.edu/eclipse/eclipse-stories-from-around-the-world
Mask of the Sun: The Science, History and Forgotten Lore of Eclipses by John Dvorak

Sources:

https://science.nasa.gov/eclipses/history/

Mask of the Sun: *https://www.goodreads.com/book/show/30334182-mask-of-the-sun*

Materials List

All Activities Support Information

Camp Example Slides

Activity 1: Solar Mysteries

- Printed *mystery cards* (preferably laminated)
- Chart paper
- Markers
- Scrap paper or notebooks
- Pencils

Activity 2: Helioviewer

- Laptops (or any device with internet connection)
- Paper
- Pencils
- Colored pencils
- *Suggested Worksheet* or use your own journal or notebook for sketching

Activity 3: Paper Plate Solar System Model

- Large paper plates (~9 inches)
- Small paper plates (~6 inches)
- *Moon template* printed on cardstock
- Coloring supplies (ex: crayons, markers, etc)
- Scissors
- Brass fasteners
- Push pin
- Long paper strips (~16in; ~ ½ in thick)
- Short paper strips (~8in; ~ ½ in thick)
- Optional: 2in hole punch
- Optional: Something to trace a small circle with

Activity 4: Layers of the Sun

- Play-doh, Model Magic or modeling clay of a variety of colors
- Clay tools (rollers, etc)
- Plastic knife
- Paper plates
- Information *Slides*
- Layers of the Sun *Visual Guide pdf*

Activity 5: Direct/Indirect

- *Earth, Sun, and Moon model* (this can also be created using Activity 3: Paper Plate Solar System Model)
- *1 tilted globe with a stand*
- 8 flashlights
- 8 globes or *inflatable Earth globes*
- *Sticky note flags*

Activity 6: Magnetic Fields

- Foam *Earth models*
- Handmade magnetometer
- Bar shaped rare earth magnets
- Standard circle magnets
- Large bowls
- Tape
- Paperclips
- Pencil
- Push pin

Activity 7: Making the Invisible Visible

- UV Beads

  Where to Purchase:
  - *Carolina Biological*
  - *Arbor Scientific*
- *Black light or UV Flashlight*
- Pipe cleaners
- Regular plastic beads
- Images of the Electromagnetic Spectrum printout
- *Worksheet* to test UV beads printout
- Pencil

Activity 8: Aurora Art

- Oil pastels
- Paper (cut in half sheets)
- Masking tape
- White paint
- Toothpicks
- Pencil
- Bowls for paint
- Paper towels or blending sticks

Activity 9: Power Outages

Per 2-3 Participants

- *6V AA battery holder* (x1)
- AA batteries (x4)
- 1 Red and 1 black *alligator clips*
- *Mini 6V light bulb* (x1)
- *Mini 1.5V light bulb* (x1)
- *Light bulb holder* (x1)
- *Modeling clay*
- Large paper clips (x2)
- *Steel wool* (grade 0)
- Cardstock sheet
- *Fuse example*

Activity 10: Secret Messages

- Glasses template, see Additional Resources for an example
- Red filter, *Lee Filters Direct in 026 Bright Red Lighting Gel*
- Green filter, *Lee Filters Direct in 090 Dark Yellow Green Lighting Gel*
- Transparent tape
- Red crayons that match the red filter
- Green crayons that match the green filter
- Index cards or white paper

Activity 11: Solar Ovens

- Closable cardboard box (see preparation section)
- Aluminum foil
- Clear plastic wrap
- Gluesticks
- Masking tape
- Ruler
- Stick or dowel to prop the lid open
- Meltable items (see preparation section)
- *Optional: Temperature gun or thermometer*
- Solar Ovens *Visual Guide pdf*

Activity 12: Solar Powered Car

- 4x6" corrugated cardboard or foam board
- Clamp lights
- Flood light (or other strong light)
- Solar Panels: *AMX3d Micro Mini Solar Cells – 1.5V 400mA 600mW Compact 80 x 60mm Solar Panels*
- *DC 1.5-3V 15000RPM Mini Electric 130 Motor Kit*
- Wheels *- 30mm x 8mm Plastic Roll 2mm Dia Shaft Toys Wheel*
- Alligator clips
- Plastic straw cut into 2 3-4 inch
- Axle *- Stainless Steel 150mm x 2mm Round Shaft Rod*
- Gear on the motor: *Modle: 092A; Number of teeth:9 ; Modulus: 0.5 Modulus; Outer diameter: 5.5mm; Hole diameter: 2mm; Thickness: 5mm*
- Gear on the axle*: Plastic Gears Model 50102A, 50 Teeth, 0.5 Modulus, 26mm Outer diameter, 5.7mm Thickness, 2mm Hole Diameter.*
- Masking tape or clear tape
- Paper clip
- Box cutter
- *(Optional)* Suggested Solar Powered Car Kits:
  - Solar Made
  - Solar DIY Micro Car Kit
  - Pitsco Kit

Activity 13: Moon Balls

- Styrofoam balls (4-5" diameter)
- Pencil
- Stationary light source with a 100 watt lightbulb. Ex:
  - Clamp light
  - Lamp without a shade
- Extension cord
- Table or chair

Activity 14: Eclipses Through History

- *Slides* (239-243)
- *Optional: Print out templates of a scroll or other suitably historic theme such as a stone template, old-looking book, etc.*
  Example of a scroll template: https://timvandevall.com/templates/blank-scroll-templates/
- Writing Utensils

Example Camp Schedules

General Daily Schedule:	
8:30 - 9:00	• Campers arrive at the museum
9:00 - 10:00	• Introduction, orientation, and warm up activities
10:00 - 12:00	• Light Exploration - *This period includes a break for a snack as well as a brief recess on the museum floor*
12:15 - 1:00	*Lunch*
1:00 - 1:30	After lunch recess
1:30 - 2:30	• Camp lessons
2:30 - 3:00	• Recap the day, discuss campers' theories, and share questions
3:00	• Camp ends

Day 1 - Monday: Intro to Mysteries
Activities Covered
• Solar Mysteries introduction activity
• Intro to helioviewer and sunspot observation
• Observation game

Day 2 Tuesday: Sun 101
Activities Covered
• Solar Mysteries activity *continued*
• Paper Plate Sun/Earth/Moon model
• Layers of the Sun
• Helioviewer and sunspot observation

Day 3 Wednesday: How the Sun Moves
Activities Covered
• Solar Mysteries activity *continued*
• Reasons for Seasons/ Direct & Indirect Sunlight
• Solar Calculators
• Sundials
• Helioviewer and sunspot observation

Day 4 Thursday: Power of the Sun
Activities Covered
• Solar Mysteries activity *continued*
• Sun Background info
• Sunprints
• Solar Ovens
• Helioviewer and sunspot observation

Day 5 Friday: Power of the Sun
Activities Covered
• Solar Mysteries activity *continued*
• Electromagnetic Spectrum
• Making the Invisible, Visible
• Helioviewer and sunspot observation

Day 6 Monday: Earth & Sun's Magnetic Field
Activities Covered
• Solar Mysteries activity *continued*
• Magnetic Fields
• Aurora Art
• Helioviewer and sunspot observation

Day 7 Tuesday: Electricity/GPS
Activities Covered
• Solar Mysteries activity *continued*
• Electricity Activity
• GPS Video
• Helioviewer and sunspot observation

Day 8 Wednesday: Living with a Star
Activities Covered
• Solar Mysteries activity continued
• Secret Messages
• Solar powered car
• Helioviewer and sunspot observation

Day 9 Thursday: Eclipse
Activities Covered
• Solar Mysteries activity *continued*
• Moon Balls
• Historical Eclipse
• Helioviewer and sunspot observation

Day 10 Friday:
Activities Covered
• Solar Mysteries activity *continued*
• Helioviewer and sunspot observation
• Final recap/theory share out
• Culminating event